STRATEGIC DEFENSE INITIATIVE

Briefing For Members Of Congress

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Director
Strategic Defense Initiative Organization

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SDI OVERVIEW

- The goal of the Strategic Defense Initiative remains unchanged: to conduct research to permit the President and the Congress, in consultation with our allies, to make an informed deployment decision in the early 1990s. President Bush, in fact, has stated, "I have taken another hard look at SDI and confirmed that the goal of the program -- providing the basis for an informed decision on deployment of defenses that would strengthen deterrence -- remains sound.

- While dynamic and dramatic global events have occurred in recent months, the Soviet offensive nuclear ballistic missile arsenal has not diminished and, in fact, is being modernized. Secretary of Defense Dick Cheney pointed out recently that, "The fact of the matter is the Soviet strategic capability...[is] more robust, more modern today than when Mr. Gorbachev took office." In addition, proliferation of ballistic missile capabilities to other nations constitutes a growing threat. The need for an aggressive research program is as compelling as it was seven years ago when President Reagan charged U.S. scientists and engineers "to give us the means of rendering these nuclear weapons impotent and obsolete." The Strategic Defense Initiative Organization (SDIO) continues to pursue that goal and has made remarkable progress.

- Research to demonstrate and validate elements of the Phase I system is balanced with tests and experiments for follow-on concepts such as directed energy technologies. The program is focused on reducing technical risk in areas such as determining target signatures of ballistic missiles, reentry vehicles and post-boost vehicles against a variety of backgrounds, communications, nuclear hardening and integration of defensive systems. The program is also focused on reducing costs in areas such as focal plane arrays, optics, light weight materials, improved system concepts and space launch. The results have been dramatic. The adoption of the Brilliant Pebbles concept has reduced the cost of development, acquisition, production and deployment of a Phase I system by 20%. The SDIO research program has also resulted in numerous technology spin-offs for both military and civilian application.

SDI OVERVIEW

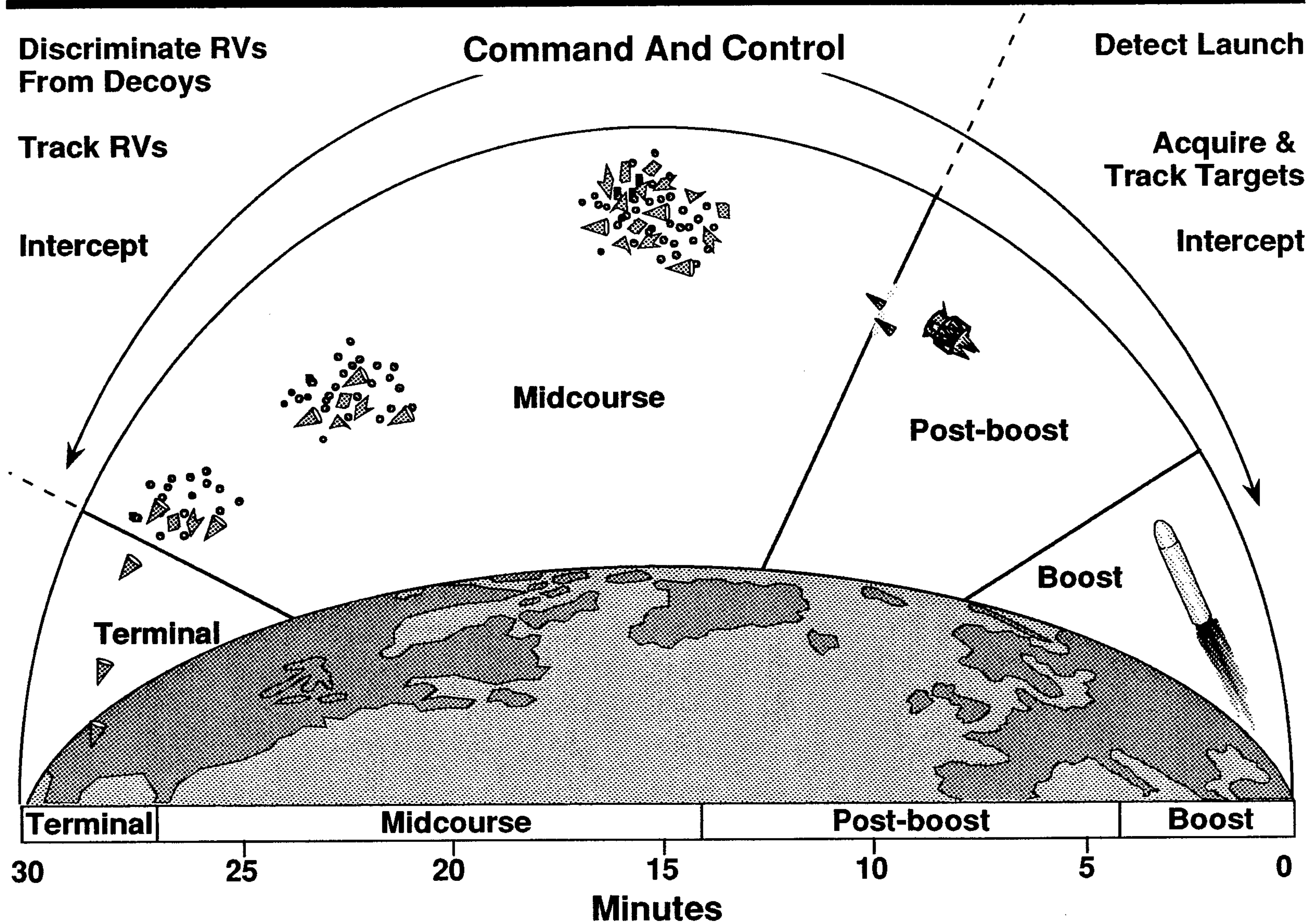
- Defensive Options Vital In Changing World Environment
- Significant Technical Progress
- Cost Trend — Down
- No Technical Show Stoppers
- Numerous Technology Spinoffs

BALLISTIC MISSILE DEFENSE CHALLENGES

- The requirements for a successful defense are to engage the attacker in all phases of the battle with many different types of weapons. This disrupts the structure of the attack and increases the cost and uncertainty of attack planning. We refer to this strategy as "defense-in-depth." We find that the concept of a defense-in-depth applies to a ballistic missile attack as well. Technology today, unlike two decades ago, provides us with the potential to deploy such a defense.

- We need multiple defensive layers capable of engaging missiles in all phases of flight. this requires defensive weapons capable of intercepting targets in the boost phase (before multiple warheads are dispensed), the post-boost phase (as the missile releases the platform or "bus" carrying all its warheads), the midcourse phase (the longest period of time as the warheads coast above the atmosphere towards their targets) and the terminal phase (as warheads reenter the atmosphere). A capable command and control system also is necessary to mange the defensive battle, as is the ability to detect and track attacking missiles and then warheads in an accurate and timely fashion. We believe strategic defense technologies researched under the SDI will provide the basis for the defensive systems necessary to build a "defense-in-depth" against a ballistic missile attack.

BALLISTIC MISSILE DEFENSE CHALLENGES



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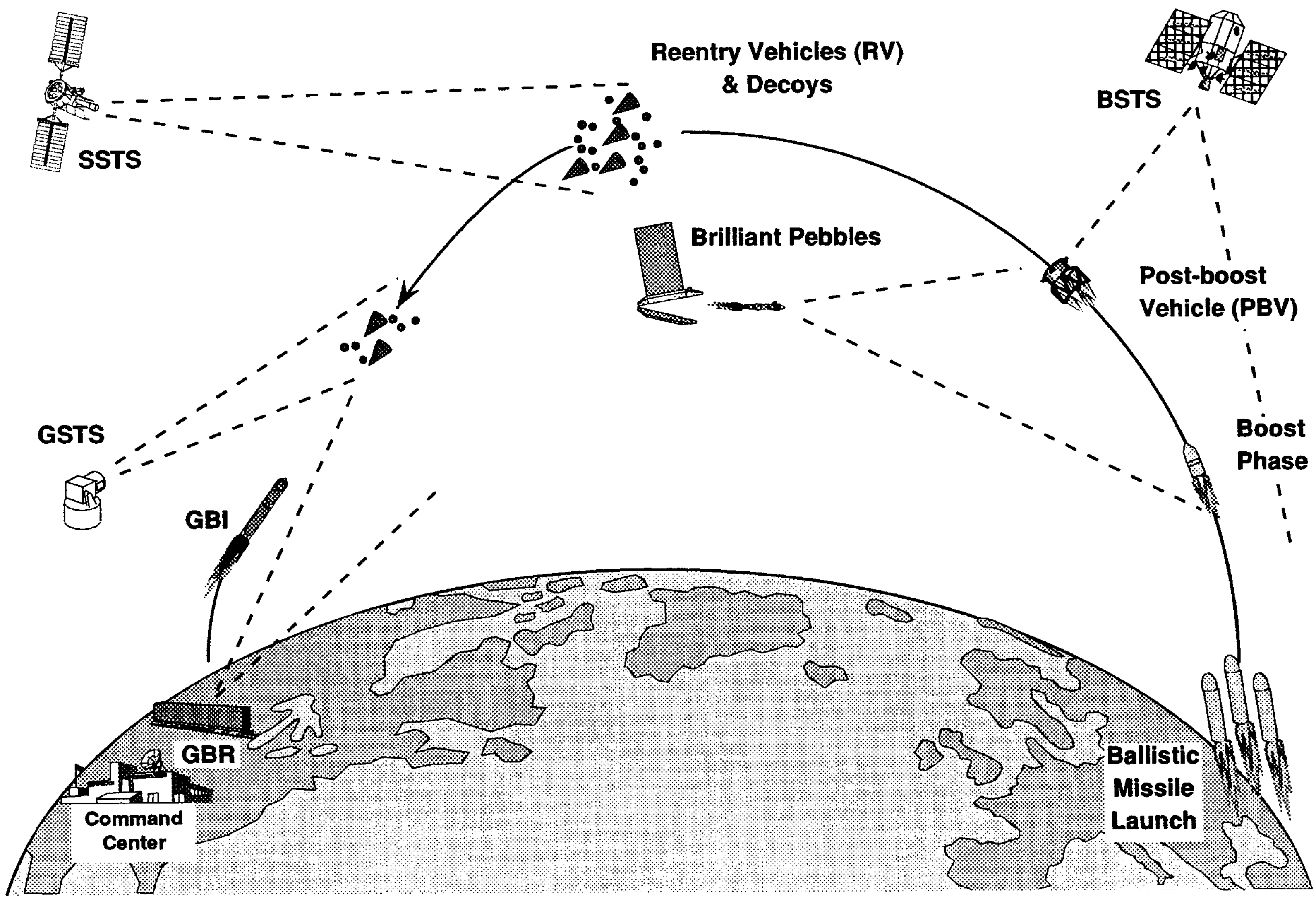
SDS PHASE I ARCHITECTURE

- The Phase I system has been designed to serve as the first in a potential series of deployments leading to a more balanced deterrent posture based on offensive and defensive forces. With this understanding, the JCS issued in 1987 a formal statement of mission objectives and required system characteristics for Phase I. These requirements provide guidance for establishing the architecture pictured below. It is a two-layer system consisting of both ground and space-based interceptors and sensors and their supporting systems.

- Layered defenses are those which engage attacking missiles in more than one portion of their trajectories. The significant benefit to layered defenses is that they are highly effective against a variety of attacks and are less vulnerable to possible countermeasures. The SDI program is consistent with this rationale. First, our research is aimed at space-based kinetic and directed energy weapons and sensors for the high payoff, <u>boost/post-boost</u> region where a single hit by a defensive weapon could destroy multiple attacking warheads and their decoys. Second, we are examining ground and space-based kinetic and directed energy weapons and sensors to detect and destroy warheads during their relatively long flights in the <u>midcourse</u> region. Additionally, we will explore ways to destroy warheads as they reenter the atmosphere in the <u>terminal</u> region.

SDS PHASE I ARCHITECTURE



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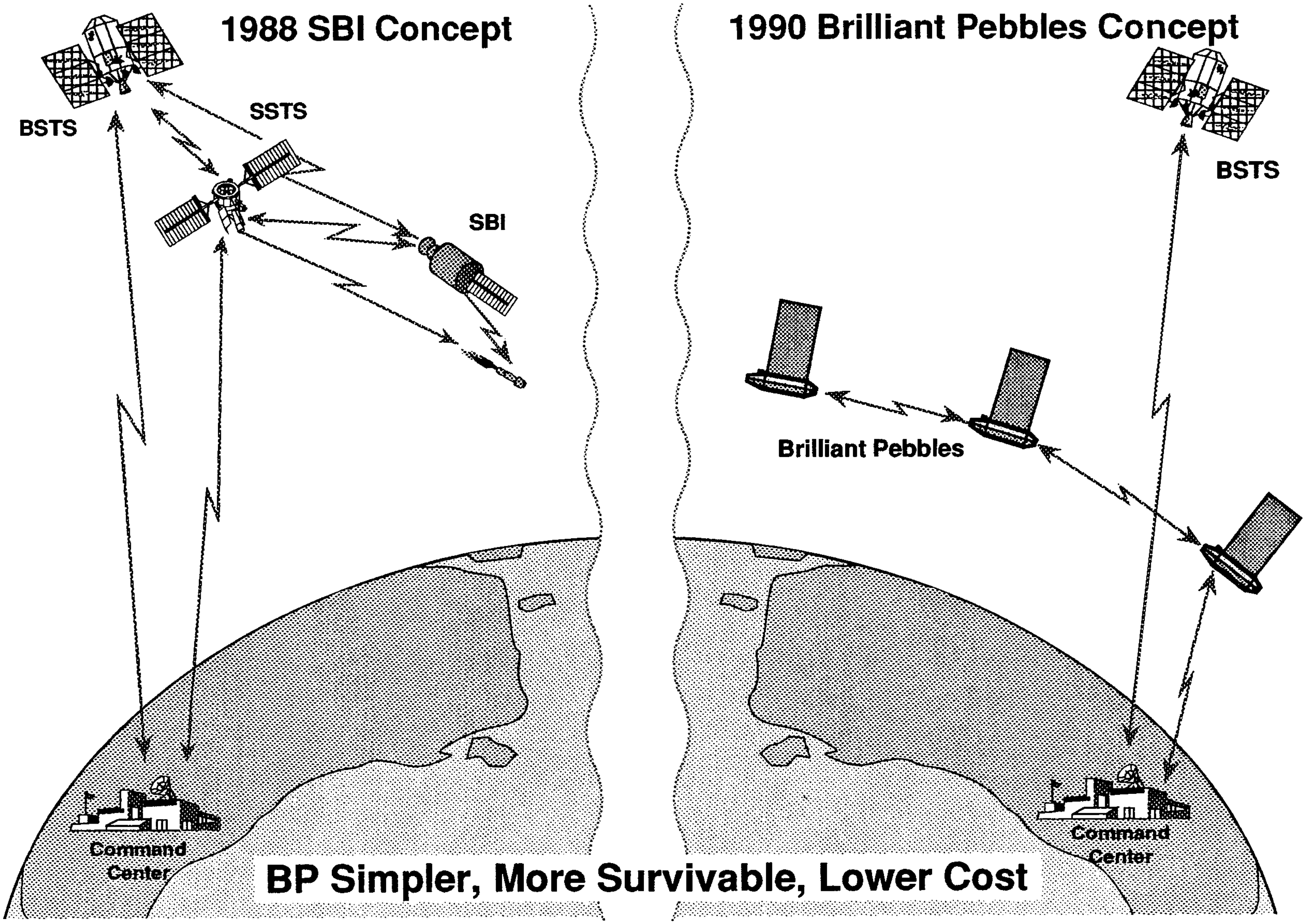
BOOST PHASE ENGAGEMENT

- The Brilliant Pebbles concept consists of a light-weight, low-cost, single hit-to-kill kinetic kill vehicle that provides integrated sensors, guidance, control, and battle management. During FY 1989, this autonomous, highly survivable, space-based defensive interceptor concept was independently reviewed by a Department of Defense Space-based Architecture Study Group, by the distinguished JASONs panel of scientists, and by the Defense Science Board. The concept was found to be innovative and capable, with no fundamental flaws, and deserving of continued support. Initial cost estimates show that Brilliant Pebbles could reduce the cost of a Phase I system by at least 20%.

- The Brilliant Pebbles concept greatly simplifies the communication required to intercept ballistic missiles and post-boost vehicles in the boost phase of flight. The Brilliant Pebbles with their autonomous capability (once given a release command) provide a highly survivable and capable boost phase defense. This chart compares the current BP architecture to the previous Space-based Interceptor concept investigated in 1988.

BOOST PHASE ENGAGEMENT



BP Simpler, More Survivable, Lower Cost

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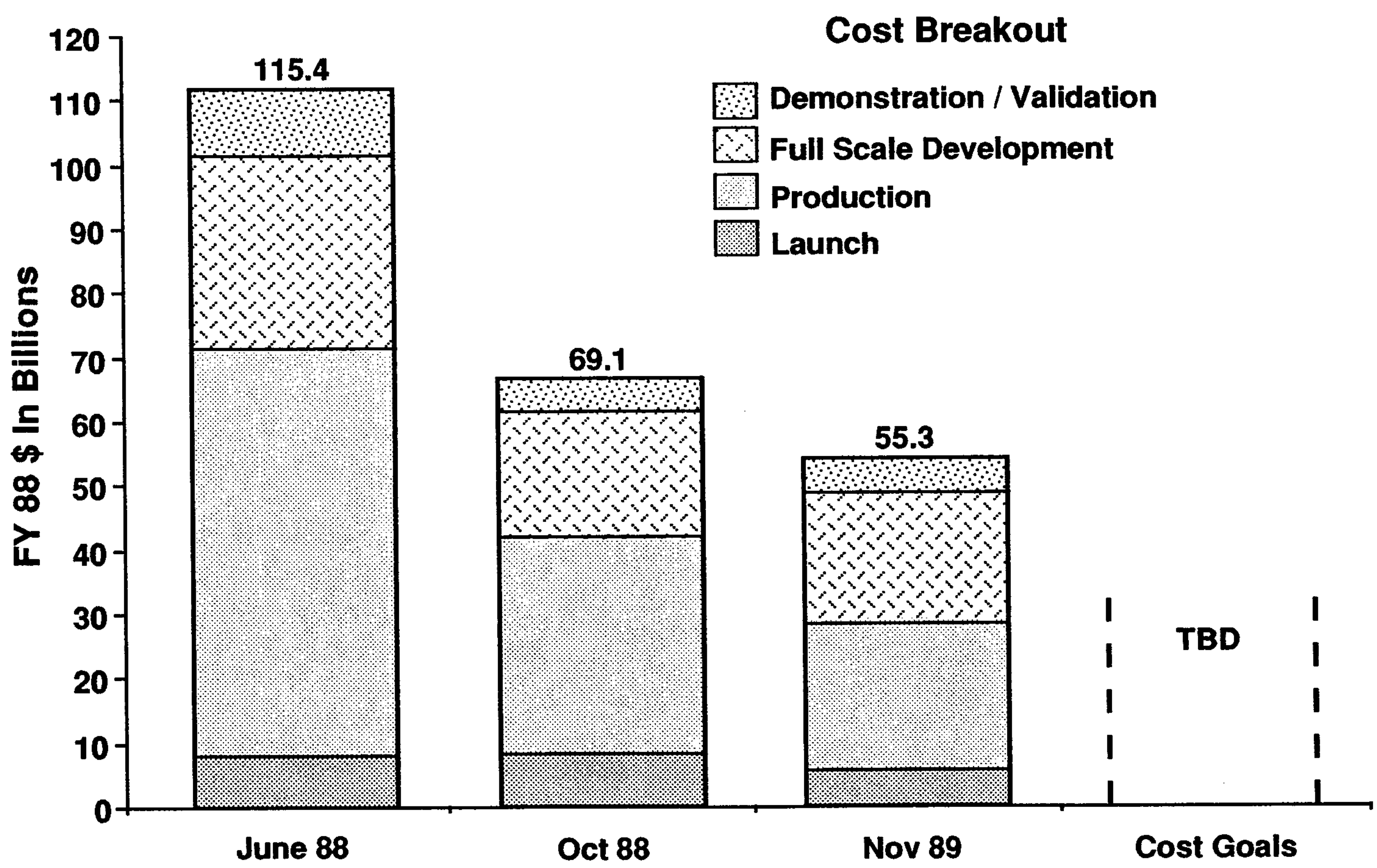
SDS PHASE I COST REDUCTIONS

- In June 1988, at a DAB review, the direction of the SDI program was affirmed and the cost of a Phase I system was estimated to be $115 billion. Significant technology advancements in many areas of the SDIO program, coupled with results of previous system concept analyses, led to a cost estimate dramatically reduced to $69 billion. These results were affirmed in Oct 1988. Since then, continued technical progress and an evolving architecture for the space-based portion of Phase I have reduced the cost figures further to $55 billion (in constant FY88 dollars).

- Potential cost reductions are most significant for the Space-based Interceptor element. The architecture outlined for the DAB in 1988 called for SBIs to be housed in several hundred Carrier Vehicles (CVs). Each CV would contain a magazine of SBIs that would orbit the earth, ready on command to attack ICBM boosters and post-boost vehicles. While that approach can meet military requirements, and rigorous testing such as the ONTARGET series confirms the technology, a study was undertaken during the summer of 1988 to find ways to reduce the cost further and increase the effectiveness and survivability of the space-based element of the system. This study examined many different space-based architectures and identified one -- the Brilliant Pebbles (BP) approach -- as a promising concept to achieve the objectives for a SDS and one that may lower Phase I costs while maintaining the level of effectiveness established by the Joint Chiefs of Staff for a SDS.

SDS PHASE I COST REDUCTIONS



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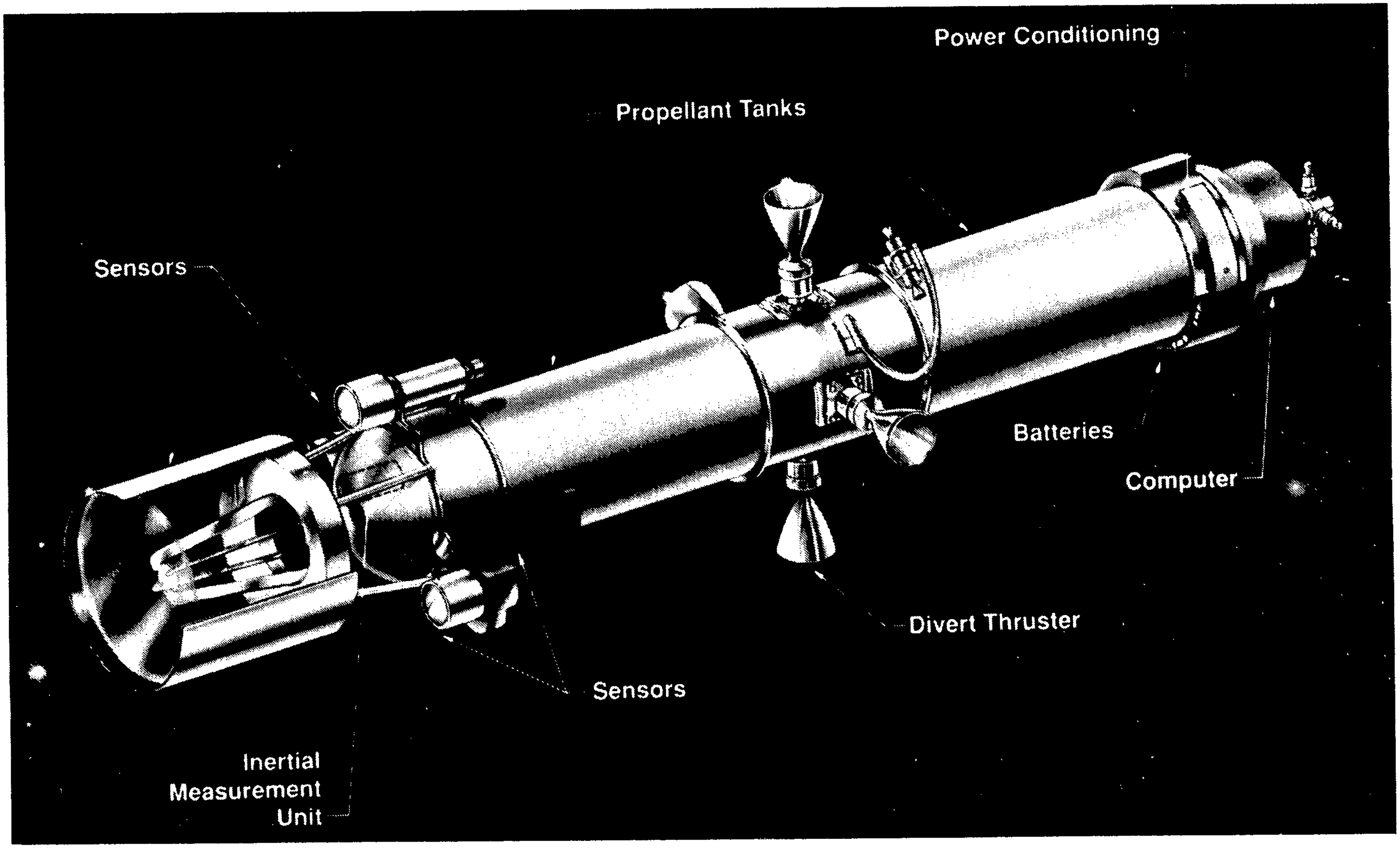
BRILLIANT PEBBLES INTERCEPTOR

- Brilliant Pebble interceptors are designed to orbit the earth in a constellation of dispersed, individual interceptors, called singlets, each with its own imaging and computing systems, propulsion, station keeping, and communications. Brilliant Pebble employs kinetic energy as its method of inflicting lethal damage on its target -- it contains no warhead, but rather destroys its target by the force of collision.

- Each Brilliant Pebbles has a star tracker that accurately and continuously determines its position. This reported back to the command center. Each Pebble also contains its own set of sensors to detect and track ballistic missile launches. Once given a release command, the Brilliant Pebbles would use its divert propulsion system to intercept and destroy these missiles and warheads.

BRILLIANT PEBBLES INTERCEPTOR



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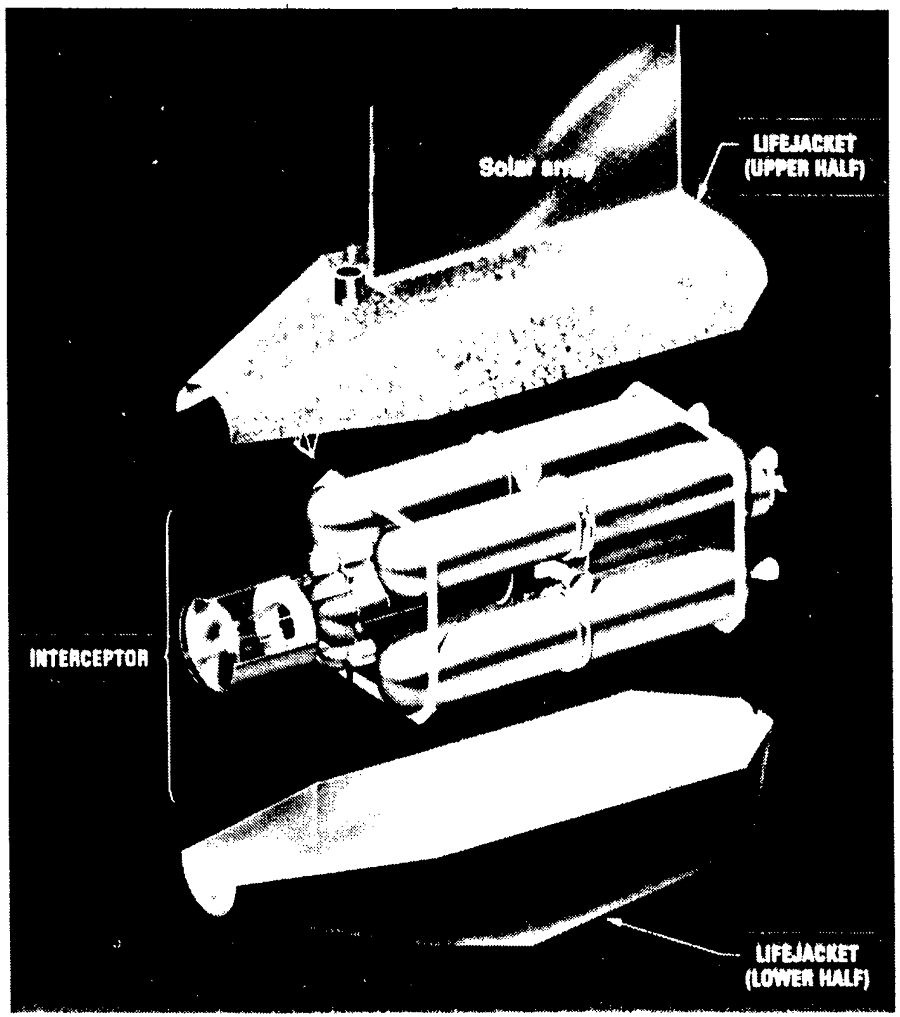
30 Mar 90

BRILLIANT PEBBLES INTERCEPTOR AND LIFE JACKET

- Each Brilliant Pebble would be launched with a "life jacket" to provide solar-derived electric power through a rechargeable battery, as well as thermal environment control and survivability options. This life jacket would be discarded after the Brilliant Pebble has been ordered to an intercept. The Brilliant Pebble interceptor and its life jacket weigh approximately 100 lbs.

BRILLIANT PEBBLES INTERCEPTOR AND LIFE JACKET



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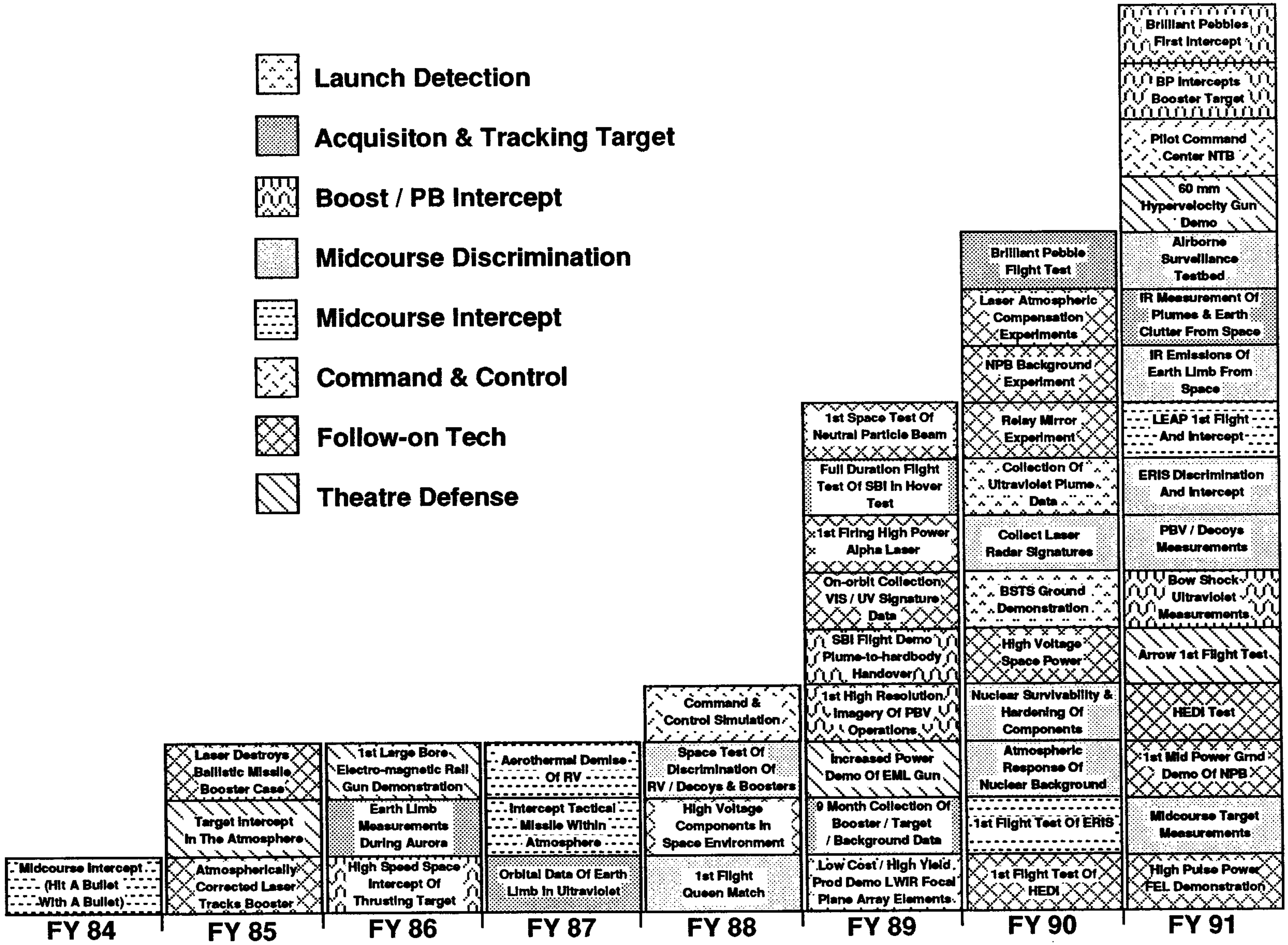
2 Apr 90

MAJOR TECHNICAL ACCOMPLISHMENTS

- The SDI program is in its sixth full year of research to determine the feasibility of effective defenses against ballistic missiles, and we continue to make excellent progress across a broad range of technologies. During FY 1989 we conducted a record number of major experiments and tests crucial to program success. The growing number of tests and experiments demonstrates that the program is moving away from paper feasibility studies, laboratory work and infrastructure development which characterized prior years. We are now moving into the test of hardware, thus capitalizing on SDI investments.

MAJOR TECHNICAL ACCOMPLISHMENTS



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ON TARGET FREE FLIGHT

- The second ON TARGET experiment was conducted on September 11, 1989, at the Air Force Astronautics Laboratory in the National Hover Test Facility. This experiment demonstrated that a space interceptor using a super high-speed computer can find and track a ballistic missile in the presence of the bright rocket plume (during the boost phase) and that target data can be processed and utilized to control attitude and position of a Kinetic kill vehicle.

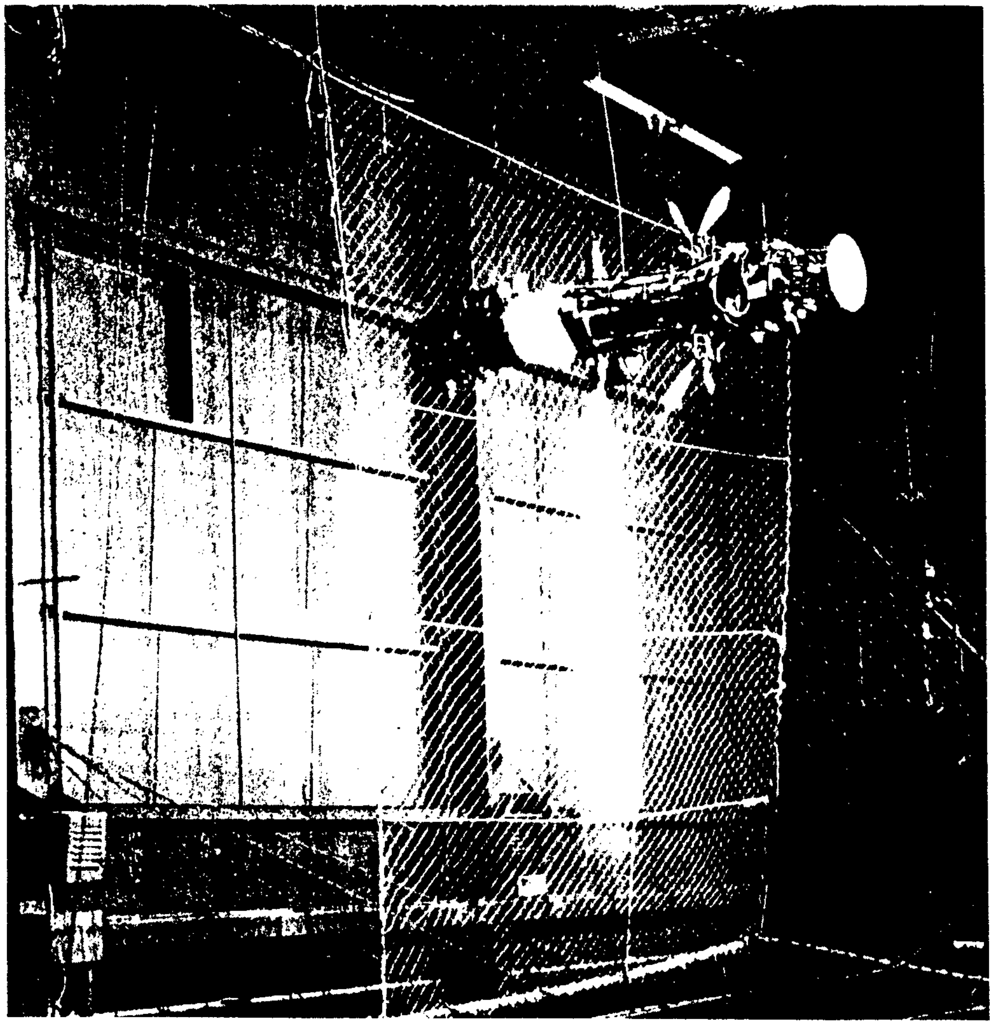
- As the interceptor flies toward its target it acquires the bright rocket plume using its mid-infrared waveband. The high speed computer, called GAPP-based image processor (GBIP) locates the front end of the imaged plume. When it is close to the missile, the intercepter switches to its long infrared waveband, where the booster body is brightest. This test of subsystems successfully proved that high speed computers can be integrated with other subsystems to guide and control the interceptor and select the correct aim point on the booster.

- The Test Vehicle is shown hovering and tracking a booster plume. The target is a booster hardbody simulator, and a solid rocket Bates motor. During the test, the vehicle motion was controlled by signals from the GBIP processed infrared sensor data in conjunction with an on-board computer and inertial guidance system. Vehicle control was maintained by 4 large divert thrusters and a series of small attitude control thrusters.

- During the experiment the vehicle initially rose to the same height as the plume simulator and tracked this using the infrared sensor and GBIP algorithms. When the Bates motor was fired the test vechicle rose slightly to be aligned with the hottest part of the rocket plume. When the sensor was switched to long wavelength, the vehicle dropped slightly to be aimed at the simulator booster. After 9 seconds of flight the test vehicle executed a programmed lateral maneuver to clear the launch cradle and executed a vertical descent to the recovery net.

- The target location is indicated by the large square spot in the picture. Initially the GBIP tracked the plume simulator. When the Bates motor fired, the GBIP located and tracked the leading edge of the plume. When the seeker switched to the longer infrared waveband the GBIP located and tracked the simulated booster after the rocket motor burned out.

ON TARGET FREE FLIGHT



TECHNOLOGY ACHIEVEMENTS

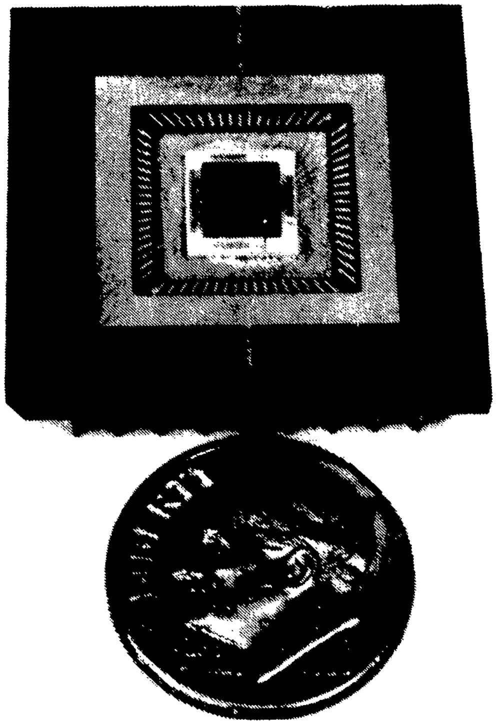
- ALL FUNCTIONS INTEGRATED ON-BOARD
- TARGET DETECTED AND TRACKED
- VEHICLE STABILITY DEMONSTRATED
- FULL DURATION FLIGHT PROFILE

90U-0091/1
3 Apr 90

IR TRACKING OF BOOSTER TARGET

- Surveillance and tracking of ICBM boosters and deployment buses utilizes the medium wave infrared (MWIR) signatures of these targets. HgCdTe is the material of choice for these sensors due to its high sensitivity to MWIR radiation at 120° K. The ability to produce large quantities of pixels at costs that would make the sensors affordable has always been an issue with HgCdTe. Pictured is a chip with the pixels configured in a 64 x 64 array used in the on-target test. Prior to SDI, only 1 of every 1000 chips had a sufficient number of working pixels to be considered acceptable, a yield of 0.1%. This resulted in the cost being $390 per pixel. The MANTECH program with the established goal of reducing the cost and increasing the yield is still underway, however, the results of the program are impressive. With two contractors in competition, Santa Barbara Research Center and Rockwell International, the yields have increased to as much as 35% and the costs have dropped to less than $0.30. At the same time, the sensitivity has increased by a factor of ten.
  - The output from the geometric arithmetic parallel processor (GAPP) is shown from a hover test of Martin Marietta's Space-based Interceptor (SBI) Kinetic Kill Vehicle (KKV). The test was performed at Edwards Air Force Base, CA, in June 1989. The picture shows the aimpoint located in the rocket plume. The GBIP used is based on a 64 x 64 processor array (4096 total) with one processor being allocated to each detector output (pixel) from the IR focal plane array. The GBIP total throughput is 40 billion operations per second, with a total weight of 46 pounds. A flight version of the GBIP is being developed by Martin Marietta and will weigh only one pound, and will be capable of 80 billion operations per second (2000 times the speed of a PDP-11 computer)

IR TRACKING OF BOOSTER TARGET



HgCdTe IR
FOCAL PLANE CHIP

GAPP-BASED IMAGE PROCESSOR OUTPUT SHOWING AIMPOINT LOCATED IN ROCKET PLUME

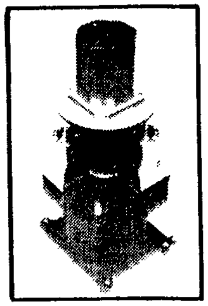
- 64 $\times$ 64 ARRAY (4096 PROCESSORS)
- 2,600 MIPS

90U-0096
16 Feb 90

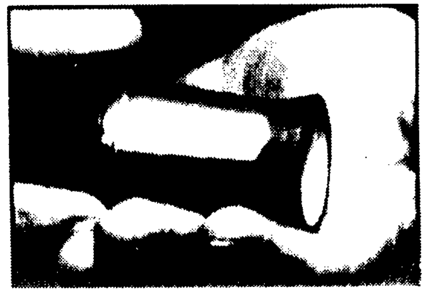
TECHNOLOGY INTEGRATION

- SDIO has invested over the last 6 year in a wide range of technologies to provide the capability to demonstrate hit-to-kill interceptors. This investment has resulted in high speed signal processor circuits, high yield low cost infrared sensors, 60 GHz miniaturized communication modules, compact high speed computers and divert and attitude control thrusters with very high thrust-to-weight performance. This technology is emerging from the laboratory and being integrated into proof of concept tests that are validating and providing confidence in strategic defense concepts. The following charts describe this progress in detail.

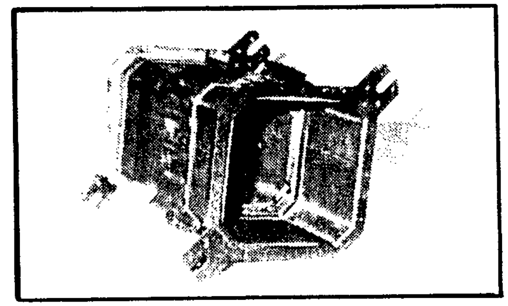
TECHNOLOGY INTEGRATION



INFRARED SENSOR



DIVERT AND ATTITUDE CONTROL SYSTEM



KKV STRUCTURE

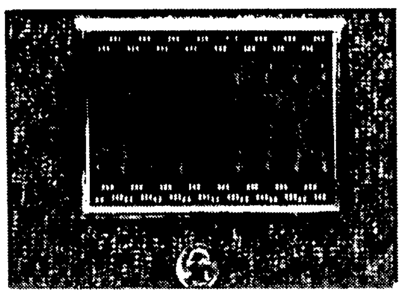
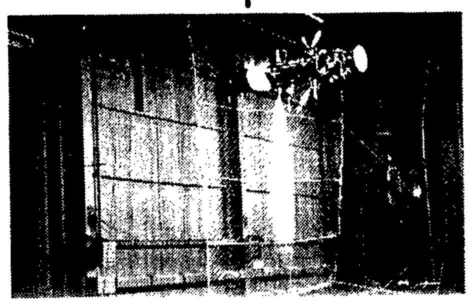
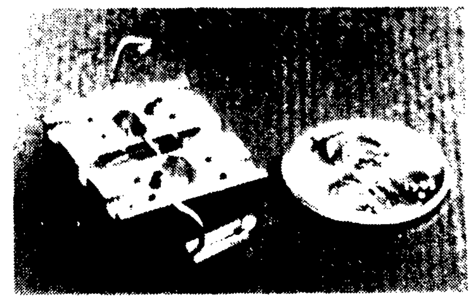


IMAGE PROCESSOR

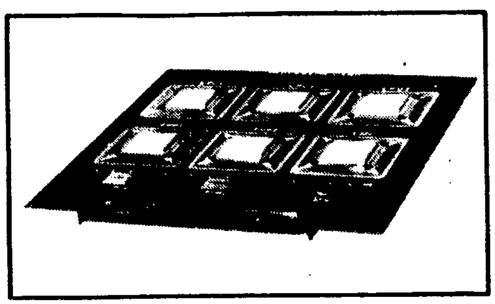


ON-TARGET



60 GHz COMMUNICATIONS

GENERIC VHSIC SPACECRAFT COMPUTER



INERTIAL MEASUREMENT UNIT

90U-0115
20 Feb 90

PARALLEL PROCESSING TECHNOLOGY

- The second on target experiment was conducted on 11 Sep 1989 by Martin Marietta for the Air Force Space Systems Division, in support of the space-based interceptor program at the Air Force Astronautics Laboratory in the National Hover Test Facility. This experiment successfully demonstrated that a space-based interceptor, using a new Martin Marietta developed super high-speed computer, can find and track a ballistic missile in the presence of the bright rocket plume and this data can be processed and utilized to control the attitude and position of a kinetic kill vehicle.

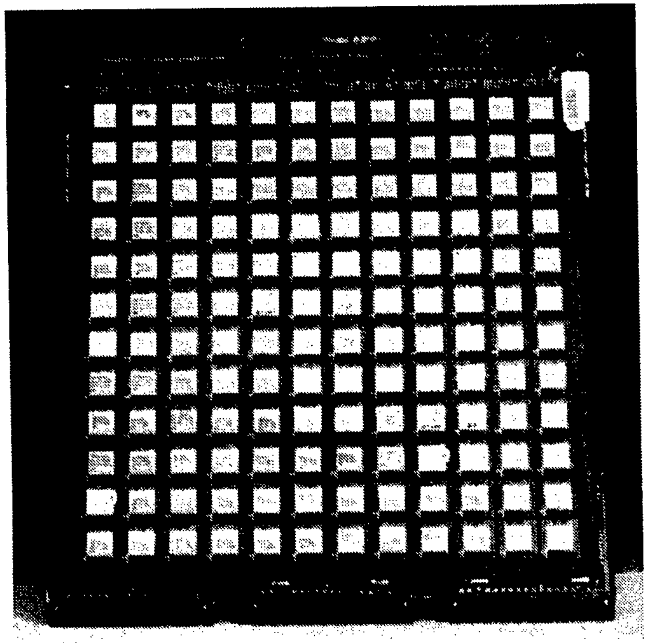
- The on-target test confirmed the ability of the GAPP computer to process image data at very high speed. Six GAPP boards, one is shown on the left, each with 128 processors operating in parallel at 40 billion operations per second (GOPS), processed the data in real time from the (64 x 64 pixel) focal plane array. The test proved that the vehicle could successfully track the booster plume and transition to the hardbody.

- The GAPP computer is now packaged on a single board (shown in the center) and contains 128 processors, each with 128 bits of storage capable of processing at 40 GOPS. For a comparison, a Cray 3 super computer operates at 1 GOP (this means it could add all of the Social Security numbers in the United States in 1/4 second). The GAPP based computer operates at 40 GOPS.

- The GAPP III based image processor using high density Z plane stacking will be capable of operating at 82 GOPS and will weigh 0.1 lb. This new technology processing combines chips in a solid cube resulting in a very high density computer. This technology is being examined for commercial application.

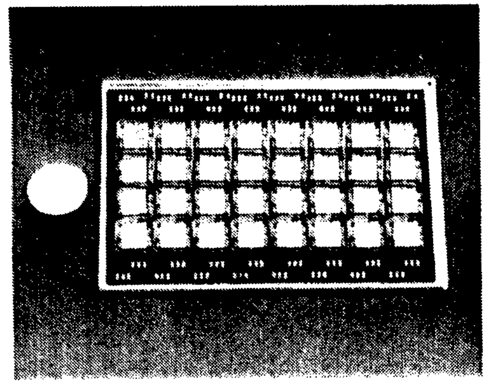
PARALLEL PROCESSING TECHNOLOGY

BRASSBOARD



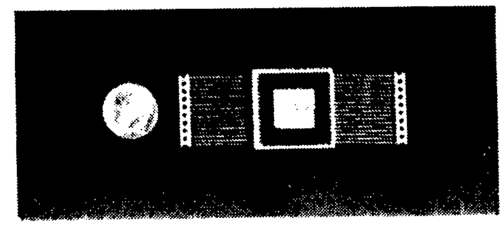
GAPP II-BASED IMAGE PROCESSOR (1987)

GAPP-BASED FLIGHT TEST COMPUTER



GAPP III-BASED IMAGE PROCESSOR (1990)

HIGH DENSITY STACKING



GAPP III (MID 90s)

	GAPP II-BASED IMAGE PROCESSOR (1987)	GAPP III-BASED IMAGE PROCESSOR (1990)	GAPP III (MID 90s)
THROUGHPUT			
OPERATIONS/SEC	—40 GOPS	—40 GOPS	—82 GOPS
INSTRUCTIONS/SEC	—1,250 MIPS	—2,562 MIPS	—2,562 MIPS
SIZE	—8.2 FT^2	—0.44 FT^2	—0.25 IN^3
WEIGHT	—45 LB	—1.2 LB	—0.1 LB
HARDNESS	—NON	—NON	—RADIATION HARD

90U-0108
20 Feb 90

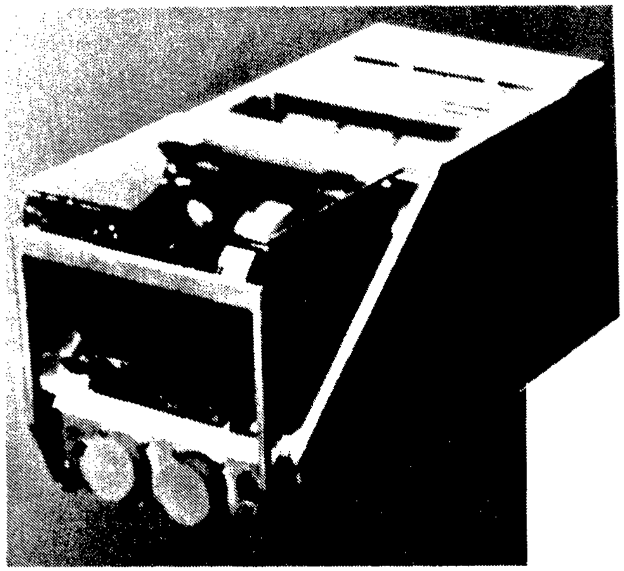
INERTIAL MEASUREMENT TECHNOLOGY

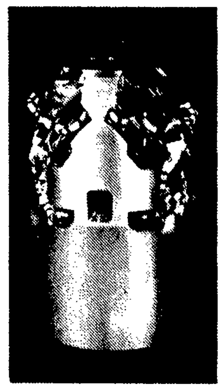
- The Inertial Measurement Unit (IMU) provides acceleration and angular rate data required by the vehicle guidance computer. These data, when processed, determine the vehicle's position in free (inertial) space. SDI is seeking lightweight interceptors for its kinetic energy weapons and is pushing the technology for substantial reductions in IMU size, weight and cost, along with improved accuracy and increased radiation hardness.

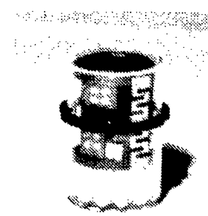
- Inertial measurement technology has experienced revolutionary advances over the last twenty years and more recently the pace of change has been accelerating. Throughout the 70s and 80s, the bulky gimballed IMUs of the past, with their mechanical spinning wheel gyros, have been replaced with smaller, lighter and more accurate strapdown tuned rotor and ring laser gyro systems. SDIO sponsored research into fiber-optic gyro technology ushers in a whole new class of IMU technology for the guidance industry in the 90s. Even more exciting is the prospect of developing, in the not to distant future, chip size, low cost micro-mechanical IMUs. The pursuit of this technology, currently under SDIO support, promises to yield a 1,000 fold reduction in weight and be 100 times less expensive than the IMUs of a decade ago.

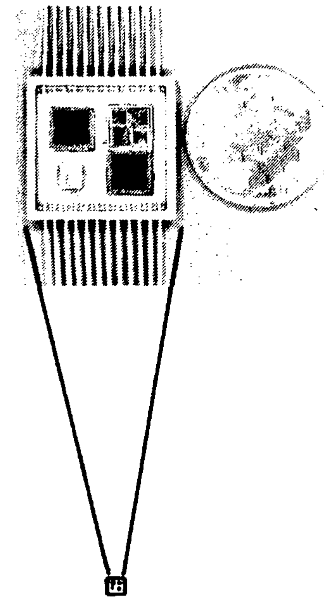
- A Technology Transfer Program has been instituted by SDIO and the Army at Draper Laboratory. Draper engineers have been working with engineers from 8 selected U.S. companies on advanced Resonant Fiber-Optic Gyro (RFOG) technology to promote the transfer of this technology to industry.

INERTIAL MEASUREMENT TECHNOLOGY









	1970s	1980s	EARLY 1990s	EARLY 1990s	MID 1990s
	GIMBALLED IMUs	STRAPDOWN IMUs	SOLID STATE IMUs	QUARTZ IMUs	MICRO-MECHANICAL IMUs
	MECHANICAL GYROS	RING LASER GYROS	FIBER-OPTIC GYROS	TUNING FORK GYROS	
	40 LB	$<$ 10 LB	$\approx$ 1 LB	$<$ 4 OZ	$<$ ½ OZ
	$\approx$ \$70,000	$\approx$ \$100,000	$\approx$ \$5,000	\$5,000	\$500
	NAVIGATION GRADE	NAVIGATION GRADE	NAVIGATION GRADE	TACTICAL GRADE	TACTICAL GRADE
ACCURACY	.005 DEGS/HR	.015 DEGS/HR	.03 DEGS/HR	1 DEG/HR	10 DEGS/HR

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20 Mar 90

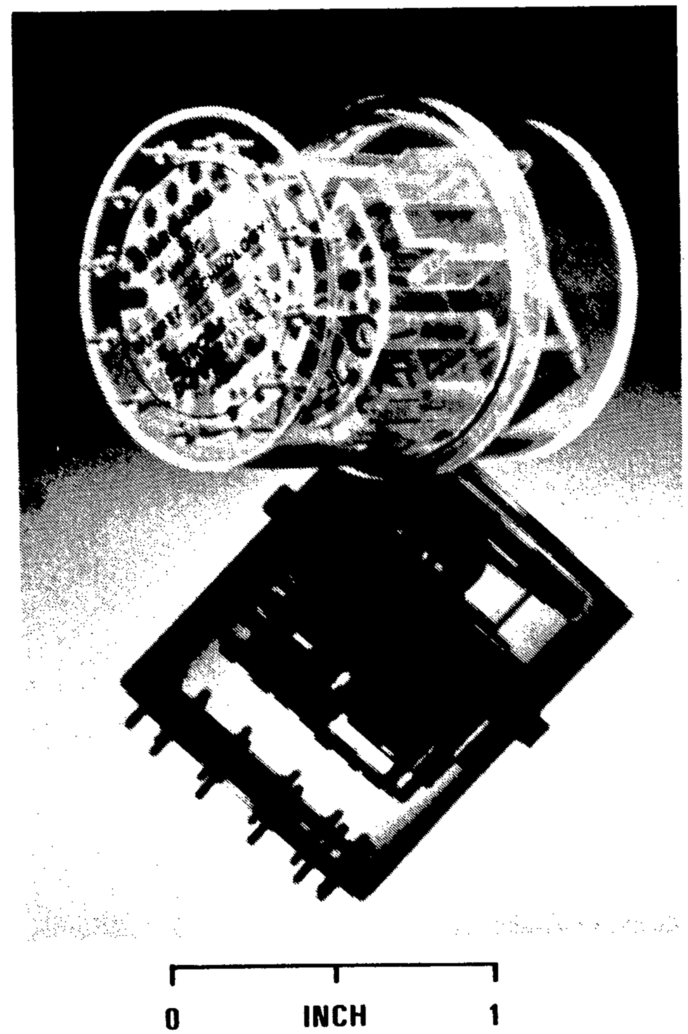
MINIATURE INERTIAL MEASUREMENT UNIT (IMU)

- Unit shown is a <u>Systron Donner</u> quartz IMU developed for SDIO
  - Utilizes 3 rate sensors, 3 linear accelerometers and associated electronics
  - Utilizes same quartz vibrational technology as digital watch
  - Provides complete 6 degree of freedom IMU
    - 1.5" dia., 3" long
    - Less than 5 watts power required
    - Weighs less than 100 grams (0.2 pounds)
    - Projected cost: $3,000 - $5,000
    - Has survived 10,000 "G" in a gun launched application
  - Inherent reliability (lack of moving parts; low part count) could provide significant maintenance and reliability improvements if retrofitted into existing IMU applications.

- Other potential applications (future)
  - Civil
    - Flight Test Instrumentation
    - GPS Navigators
    - Robotic Servo Control Systems
    - Automated Manufacturing
    - Aircraft Stabilization and Control Systems
    - Active Suspension Systems (Automotive)
    - Active Landing Gear Systems (Aircraft)
    - Anti-skid Systems

MINIATURE INERTIAL MEASUREMENT UNIT (IMU)

- "MICRO IMU" DEVELOPED BY SDI FOR USE IN INTERCEPTORS:
  - UNDER EVALUATION FOR USE IN:
    - U.S. ARMY HELLFIRE MISSILE
    - U.S. ARMY NON-LINE-OF-SIGHT (NLOS) MISSILE
    - MULTINATIONAL MLRS TERMINALLY GUIDED WEAPON (TGW)
    - U.S. ARMY STABILIZED IR SEEKER (SURVIVES GUN LAUNCHED 10,000 G's)
    - U.S. ARMY TERMINALLY GUIDED SUBMUNITION
    - U.S. NAVY SHIPBOARD SATCOM STABILIZATION



90U-0089
16 Feb 90

COMMUNICATIONS COMPONENT DEVELOPMENT

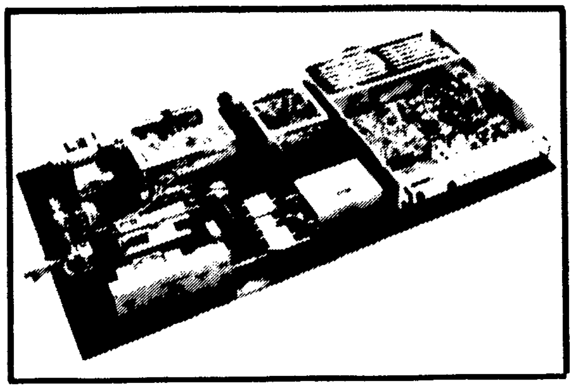
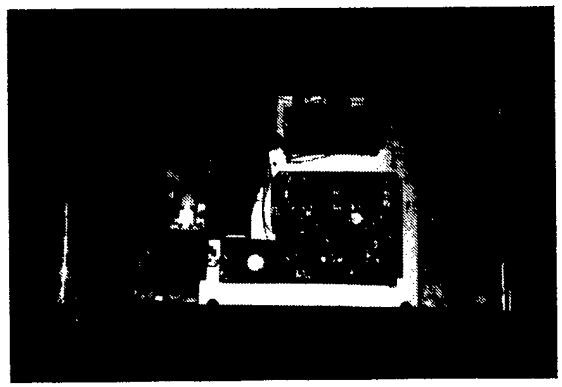
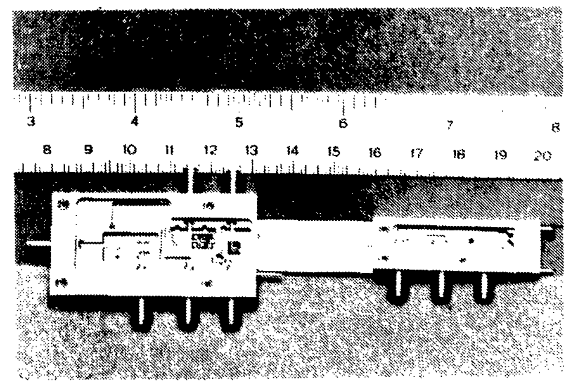
- 60 GHz for space to space communication links provides higher data rates, lower weight and increased survivability
  - Nuclear effects on communications are frequency dependent and cause
    - Signal fading, limited bandwith, ionization effects
  - Higher frequencies such as 60 GHz combined with the signal processing techniques listed alleviate these effects
    - Signal Coding
    - Interleaving
    - Diversity (multiple transmission paths)
    - Adaptive equalization
  - Jamming may also degrade communications channels
    - 60 GHz is absorbed by an oxygen absorption line in the atmosphere and is therefore, less susceptible to ground or aircraft-based jammers

- Advances in integrated circuitry initially reduced size and weight. MMIC technology further reduced the weight, and more importantly, reduced the production times from months to days with a corresponding 10-fold decrease in cost.

- The components designed for the SDS will operate in the 60 GHz frequency spectrum. A 60 GHz receiver that has been demonstrated in bench tests is shown on the right. It weighs 1.3 oz and can be carried on individual interceptors like Brilliant Pebbles.

COMMUNICATIONS COMPONENT DEVELOPMENT

PROGRESS IN COMMUNICATIONS TECHNOLOGY (60 GHZ COMMUNICATIONS RECEIVER)

	1979	1985	1989
			
PRODUCTION	≈ 180 MAN DAYS	≈ 30 MAN DAYS	≈ 2 MAN DAYS
WEIGHT	≧ 60 LBS	≧ 3 LBS	≧ 1.3 OZ
POWER CONSUMPTION	40 WATTS	20 WATTS	5 WATTS

90U 0087
16 Feb 90

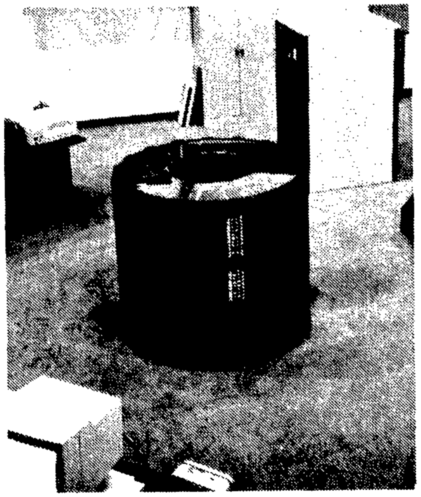
COMPUTER ADVANCES

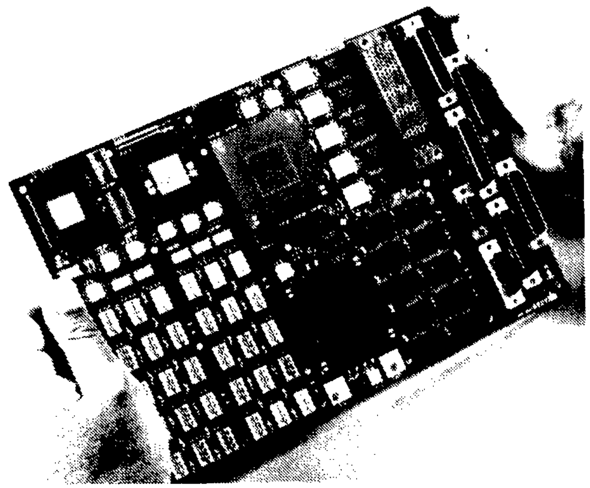
- The computer required for the Brilliant Pebbles hit-to-kill interceptor with the capability to do all data processing, target acquisition, tracking, station keeping and Battle Management is shown. These very high speed capability computers can be assembled in very small packages (size of a deck of playing cards)
  - The BP Computer possesses the processing speed and data throughput capability of an early super computer (shown compared to a Cray-1)
    - -- The large memories characteristic of most super computers are not required for BP (128 Megabyte versus 4 for BP)
  - The BP computer is hardened to the space natural and nuclear blast environment

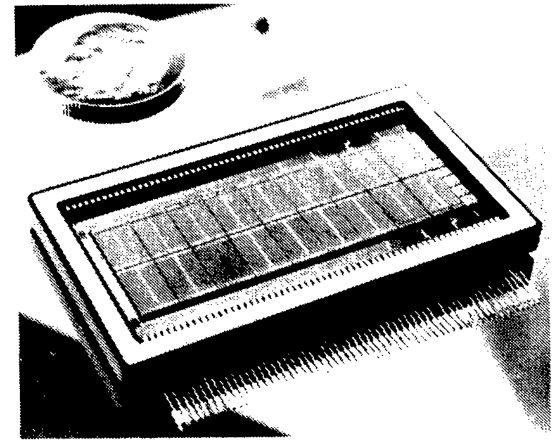
- The BP flight test computer shown in the center picture has been bench tested at LLNL and is being readied for the first BP flight test

- One of the 4 modules required for the final miniaturized BP computer is shown on the right. This computer memory chip and associated interconnect technology was successfully tested in an underground nuclear test to verify radiation hardness. The miniaturized BP computer will be flown on a BP test in 1991.

COMPUTER ADVANCES







	CRAY 1	BP FLIGHT TEST COMPUTER—1989	BP FLIGHT COMPUTER—1991 (1 OF 4 MODULES)
PROCESSORS	1	1	2
MEMORY (MEGABYTE)	128	2	4
MILLION INSTRUCTIONS PER SECOND (MIPS)	36	12 SUSTAINED 20 PEAK	24 SUSTAINED 40 PEAK
SIZE (FT^3)	188	0.06	0.015
WEIGHT (LB)	10,000	3.0	0.5
POWER (WATTS)	100,000	28	66

900 0118 1
3 Apr 90

FOCAL PLANE ARRAY (FPA)

- This Mercury Cadmium Telluride (HgCdTe) Focal Plane Array is the key Medium Wavelength Infrared (MWIR) sensor used in the boost phase for optical detection of Post Boost Vehicles (PBVs) and Reentry Vehicles (RVs). The sensor supports BSTS and SBI. Photons in the infrared band 5-9 um wavelength are sensed by the IR elements in the array and compared to known signatures in the on-board sensor processor.

- The array is made from a line of silicon chip pixels impregnated with the HgCdTe. The strings of pixels are grouped into arrays and the signal processing is compatible with one of the groupings.

- Pixel producibility, increased sensitivity to photons and resistance to radiation have been the focus of SDIO's technology efforts in this area. Pixel production yields are being improved from a few percent of acceptable pixels produced in a laboratory environment as demonstrated in FY 89, to low rate manufacturing processes yielding several million pixels per year. The goal is 20 million per year in 1993. The higher rate and improved production processes will also reduce the cost dramatically.

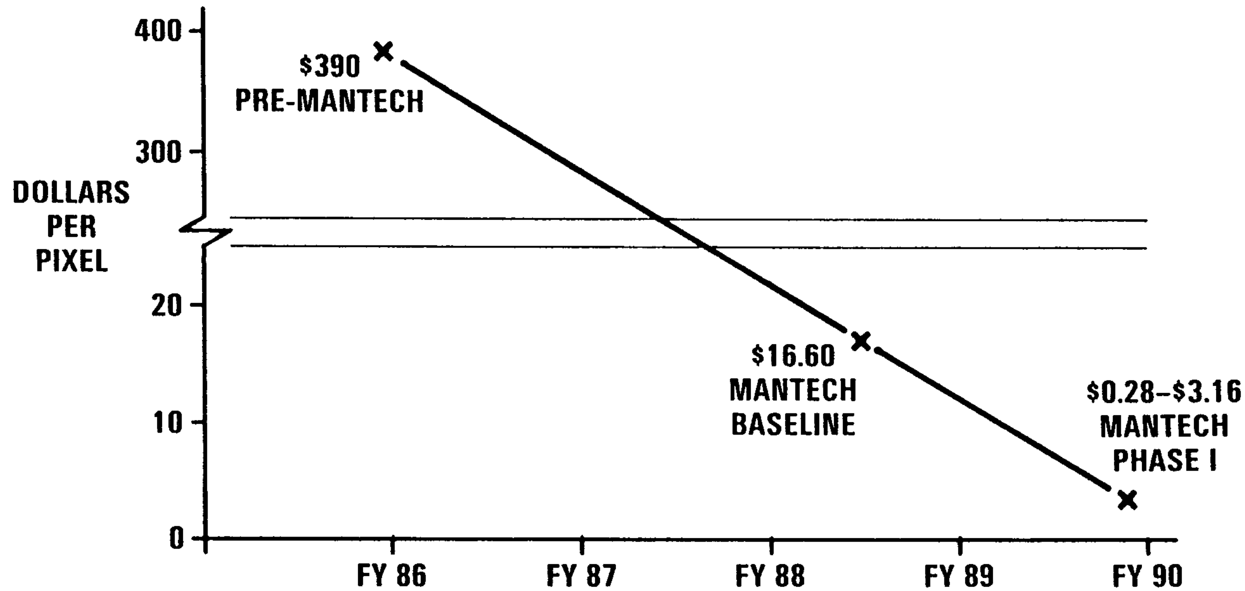
- While the MWIR FPA supports the BSTS, the overall technology development supports all SDIO sensors, including the LWIR sensors used by SSTS, GSTS and DEW concepts. In addition, such technology improvements have wide ranging applications in DoD.

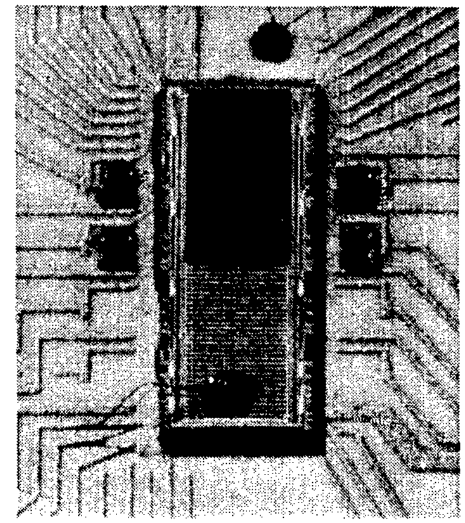
- This slide shows a Focal Plane Array in the very center of a circuit board surrounded by processing circuits on this test board.

- This array is a 32 x 64 array. The processes developed will provide the foundation for even larger boards in the future.

FOCAL PLANE PRODUCIBILITY

MANTECH PROGRAM TO PRODUCE MERCURY CADMIUM TELLURIDE (MCT) MWIR FOCAL PLANE DETECTORS FOR BOOST PHASE SURVEILLANCE





	PRE-MANTECH	TODAY
YIELD	< 0.1%	11–35%
SENSITIVITY	1	3X
SIZE OF DETECTORS	(2 x 64)	(32 x 64 128 x 128)
UNIFORMITY (VARIABILITY)	30%	4%
PRODUCTION CAPACITY/YEAR	< 1,000	2,000,000

90U-0099
20 Feb 90

DIAMOND MATERIALS

- SDIO Diamond Technology Initiative started in 1986
  - Managed by Office of Naval Research for SDIO Innovative Science and Technology Office (IS&T)
  - Goal of initiative is nucleating (depositing or growing) single crystal diamond films on economical substrates

- Diamond offers the "best" and "most" in many categories of interest to the defense industry
  - Hardness
  - Thermal conductivity
  - Corrosion resistance, radiation hard, non-toxic
  - Transmissivity across a broad spectral range
  - Epitaxial deposition (easy to deposit on irregular surfaces)
  - Electrical properties
    - -- Insulating when pure
    - -- Semi-conducting when doped
    - -- Faster than silicon or gallium arsenide
    - -- Can be etched into circuits

- Diamond may suplant silicon for use in fast, stable, heat tolerant circuits (32X better in overall semi-conductor performance than silicon)

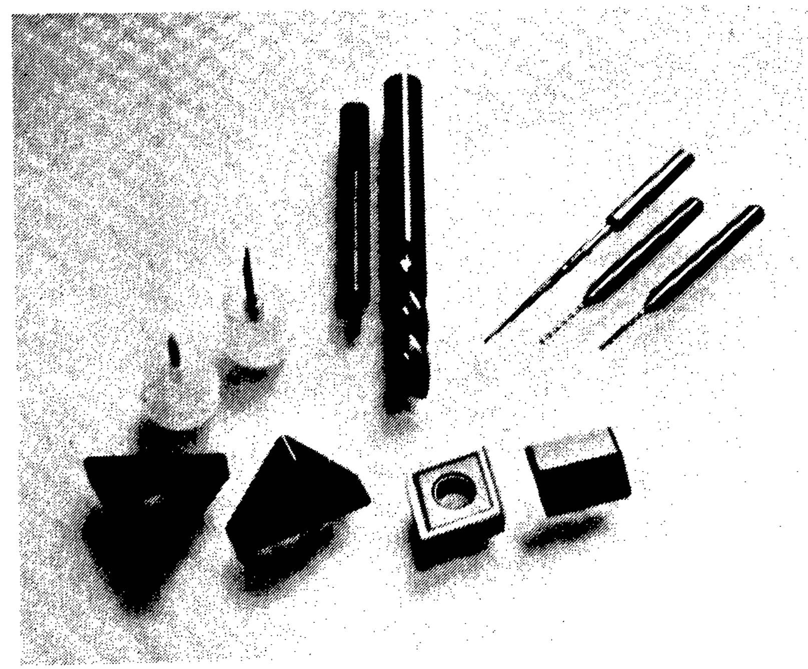
- Numerous other defense uses in materials, sensors / optics, electronics, survivability, etc.

- CRYSTALLUME making commercially available polycrystalline diamond films using the chemical vapor deposition process, and was (is) the only U.S. company to do so. Monocrystalline diamond development began in 1987.

- Funding for diamond technology is $10M / yr. Japan is currently spending more than ten times that amount for diamond coating.

DIAMOND MATERIALS

- SDIO: FIRST SPONSOR OF U.S. DIAMOND FILM RESEARCH AND DEVELOPMENT
  - SDIO SUPPORT RECOGNIZED IN BUSINESS WEEK MAGAZINE
- DIAMOND'S UNIQUE PROPERTIES HAVE MANY POTENTIAL APPLICATIONS TO A WIDE VARIETY OF PRODUCTS
  - POTENTIAL FOR $16 BILLION MARKET BY THE LATE 1990s
  - NUMEROUS APPLICATIONS TOOLING, ELECTRONICS, MATERIALS,
    etc.
  - SUCCESSFUL START-UP: CRYSTALLUME, MENLO PARK, CA



90U-0104/1
12 Mar 90

COMPACT ACCELERATORS

- Linear accelerator technology originally intended for SDI directed energy applications and developed by the Los Alamos National Laboratory (LANL) has found many potential commercial applications. Originally a Soviet concept, proposed in 1970 that filled a three story room in its first versions, has been reduced by LANL to a table-top size accelerator. The Radio Frequency Quadrupole Linear Accelerator (RFQ LINAC) design from LANL (shown in the insert) was commercialized by AccSys Technology, Inc., Pleasanton, CA. Several applications have resulted.

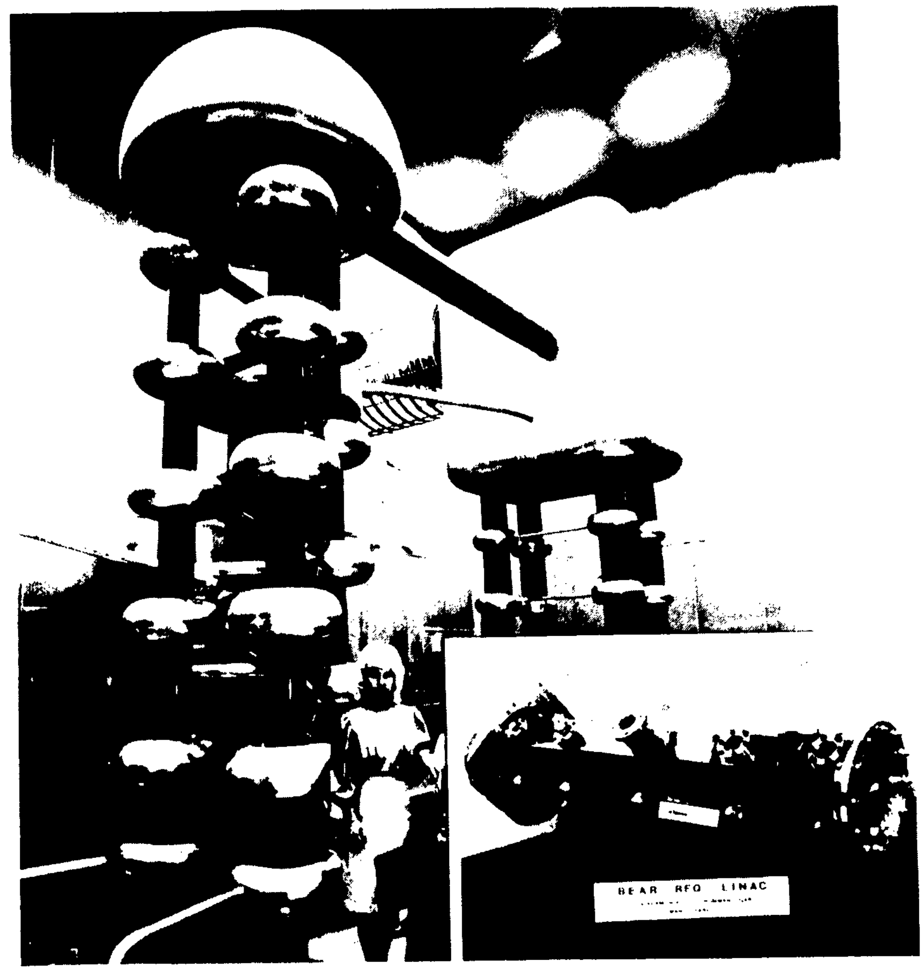
- <u>Medical Diagnostics</u>: The RFQ LINAC is being used to produce the radio pharmaceuticals used in Positron Emission Tomography (PET), a non-invasive medical imaging technology which produces false color images of the body's metabolic activity.
  - Current technology to produce the radioactive isotopes required large, heavy and expensive accelerators (20-30 ton cyclotrons). In addition, the half-life of the isotopes needed for PET are short lived. Few hospitals could afford to set up the facilities to produce the isotopes, or were too far from existing production facilities, severely limiting the powerful diagnostic promises of PET.
  - The compact RFQ LINAC from SDI research now makes it possible for more hospitals and research facilities to use PET in medical diagnosis.

- <u>Medical Treatment</u>: The Loma Linda University Medical Center in southern California has constructed a facility using the SDI developed RFQ LINAC for a proton therapy cancer treatment facility. Construction of the facility is complete and use of the LINAC in the clinical setting is expected early in 1990.

- <u>Explosive Detection</u>: AccSys Technology has sold a SDI derived RFQ LINAC to the FAA, who plan to develop a program using the device. Current explosive detection devices used at a few commercial airports use a proton generator to bombard potentially explosive materials. The RFQ LINAC should be able to provide a similar energy source, requiring less shielding, making it more relocatable.

COMPACT ACCELERATORS

- RADIO FREQUENCY QUADRUPOLE LINEAR ACCELERATOR (RFQ LINAC) CURRENT APPLICATIONS:
  - RADIO PHARMACEUTICAL PRODUCTION FOR POSITRON EMISSION TOMOGRAPHY (PET)
    — RFQ ALLOWS WIDER USE OF THIS POWERFUL TECHNIQUE
  - CANCER THERAPY AND TREATMENT
    — LOMA LINDA UNIVERSITY MEDICAL CENTER PROTON THERAPY UNIT
  - EXPLOSIVE DETECTION
    — UNDER EVALUATION BY FAA



90U-0084
16 Feb 90

LEAP SEEKER TECHNOLOGY

- The seeker shown contains an infrared sensor that is extremely lightweight and provides high sensitivity, high resolution, and wide dynamic range. This sensor was produced by Hughes for the Light Weight Advanced Technology Hit-to-kill Interceptor Program (LEAP).

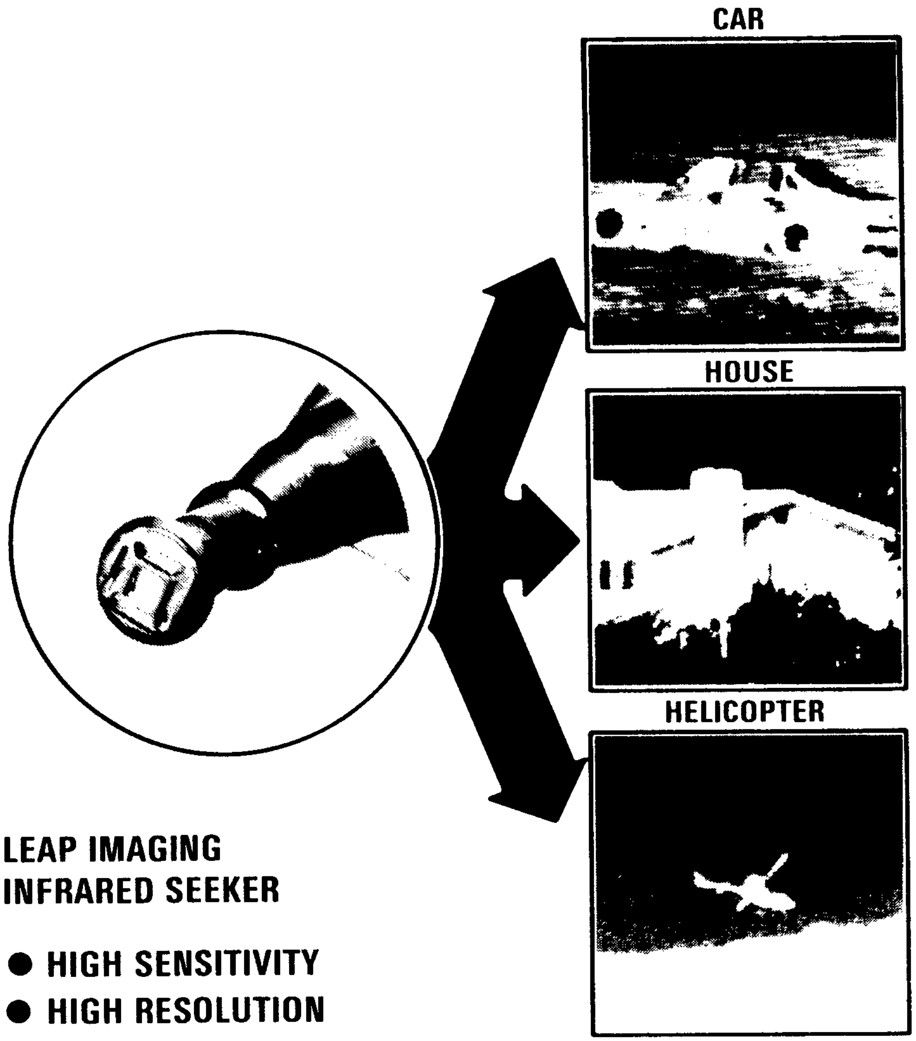
- Because the thermal characteristics of objects change very little from day to night, this LEAP seeker provides a high resolution image regardless of whether it is imaging during the day or night. The electronics can be programmed to acquire and track different targets. These targets can be hot spots -- such as a hot plume or objects cooler than background. While this sensor is ideally suited to military applications, such as acquiring and tracking strategic and tactical targets, it has many non-military applications as well.

- The LEAP sensor provides vision at night with many potential applications.

- Sensor imaging could also be used in collision avoidance systems and autonomous vehicle guidance. Using a ranging device in combination with this sensor, a collision avoidance system could be developed. Specified recognition patterns could be mounted to allow autonomous vehicle guidance.

- High sensitivity and high resolution allow immediate recognition of fires as well as the potential to detect human and animal survivors during rescue operations.

LEAP SEEKER TECHNOLOGY



LEAP IMAGING
INFRARED SEEKER

- HIGH SENSITIVITY
- HIGH RESOLUTION
- WIDE DYNAMIC RANGE

POTENTIAL APPLICATIONS

- NIGHT VISION
  - LAW/DRUG ENFORCEMENT
- SENSOR IMAGING
  - AUTONOMOUS VEHICLE GUIDANCE
  - COLLISION AVOIDANCE
- FOREST MANAGEMENT
  - FIRE DETECTION

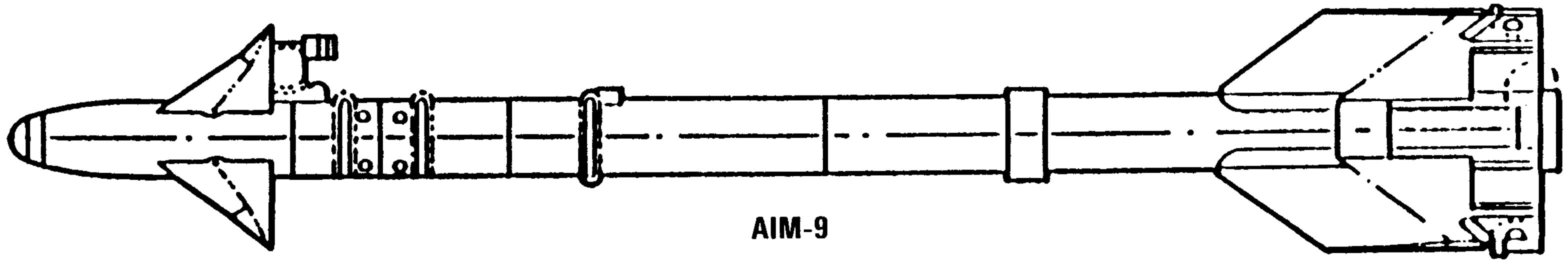
90U-0083
16 Feb 90

AVIONICS TECHNOLOGY SPINOFFS

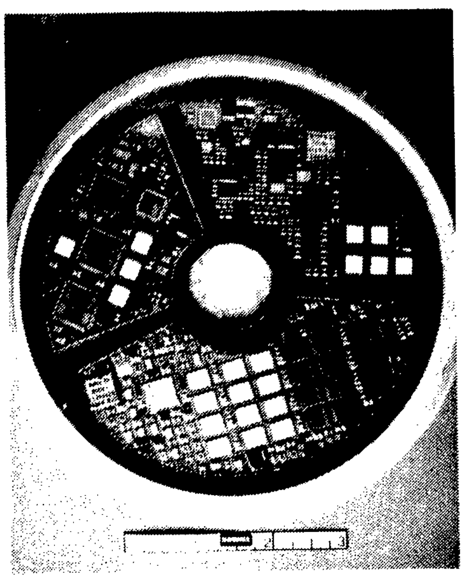
- The current AIM-9R imaging IR seeker has approximately 12 inches of 5-inch diameter cards for all of the avionics. About two inches of this is dedicated to the drive electronics for the actuators. The remaining 10 inches could be repackaged, using LEAP avionics technology (80386 processors and hybrid wafer scale integration), into about one inch. The weight savings associated with the repackaging would be a reduction from 16 pounds to one pound. Furthermore, a simple scaling down of propulsion for the lighter payload would result in an additional 20 pounds reduction.

- There are other potential technology changes which would further reduce the AIM-9 missile size, such as relying on tail control, hit-to-kill guidance, and an overall smaller diameter air frame (four inches). Hit-to-kill guidance is now possible using the algorithms and guidance and control systems developed for LEAP, HEDI, GBI, and SBI. The resulting AIM-9 would weigh as little as 100 pounds: a 43 percent reduction from the initial 176-pound AIM-9R.

AVIONICS TECHNOLOGY SPINOFFS



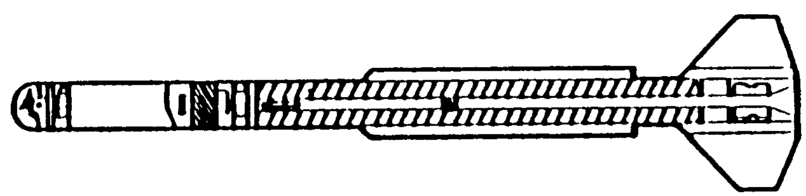
AIM-9



LEAP AVIONICS
(HYBRID WAFER SCALE INTEGRATION)

POTENTIAL FOR AIR-TO-AIR MISSILE

- 43% TOTAL WEIGHT REDUCTION
- 10 INCHES OF AVIONICS REDUCED TO 1 INCH
- 16 LBS OF AVIONICS REDUCED TO 1 LB
- REDUCTION IN PROPULSION REQUIRED
- REDUCED DIAMETER, HIT-TO-KILL, SMALLER TAIL CONTROL SURFACES



90U 0098
16 Feb 90

LASER TECHNOLOGY APPLICATION

- New applications of the pulsed CO_2 laser in combination with a new imaging procedure in the treatment of burns.

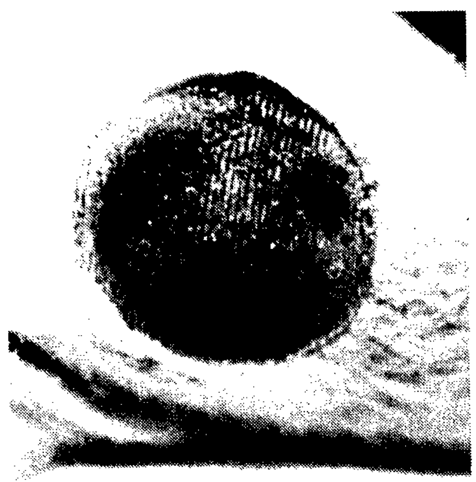
- The theory of surgical burn management is to identify the extent and the depth of the burn and subsequently debride the necrotic tissue as close to the viable tissue as possible. The viable or living tissue thereafter can sustain skin grafts. In large burns this is prohibitive, as the only way to identify living tissue is to use bleeding as an end point. In these large cases, too much blood is lost in the debriding process. As a result, many burn surgeons excise down to the next landmark which is the fascia over the muscle. This sacrifices too much normal tissue.

- Recent developments in the Wellman Laboratories utilizing the pulsed CO_2 laser may make it the ideal tool to debride burn eschar. By utilizing this new technology, large areas of dead skin may be ablated rapidly with great precision and accuracy of depth, due to the achievement of high peak power and short pulse intervals. Little residual thermal damage is produced by this procedure, so the ensuing bed remains viable and capable of sustaining a graft. Also due to the laser, hemostasis is achieved immediately.

- This laser modality is further aided by a new imaging technique, also developed in the Wellman Laboratories. This is a new method of assessing early and accurately the depth of the necrotic burn. The imaging technique utilizes a nontoxic intravascular dye (indocyanine green) which is excited by two wavelengths of infrared light. The image of the florescence of this dye can be utilized to identify which tissue needs laser excision and which tissue is living and able to sustain a graft.

LASER TECHNOLOGY APPLICATION

EXCISION BY SCALPEL



EXCISION BY LASER

PULSED CO_2 LASER WITH NEW IMAGING PROCEDURES APPLIED TO THE TREATMENT OF BURNS

- REPLACES SURGICAL METHODS REQUIRING MULTIPLE OPERATIONS
- LARGE AREAS OF DEAD SKIN ABLATED RAPIDLY WITH GREAT PRECISION AND ACCURACY
- REDUCED SCARRING
- PROVIDES EXCELLENT BASE FOR SKIN GRAFTS

GEL TECHNOLOGY SPINOFFS - CONTROLLED EJECTION

- Smart ejection seats would assist in preventing pilot death and injury during emergency ejection. A smart seat would consist of gyros, guidance processors, and a gel-based attitude control system for seat orientation and control. Gel propellants are better than the conventional solid propellants, since they can be pulsed and throttled for greater seat control.

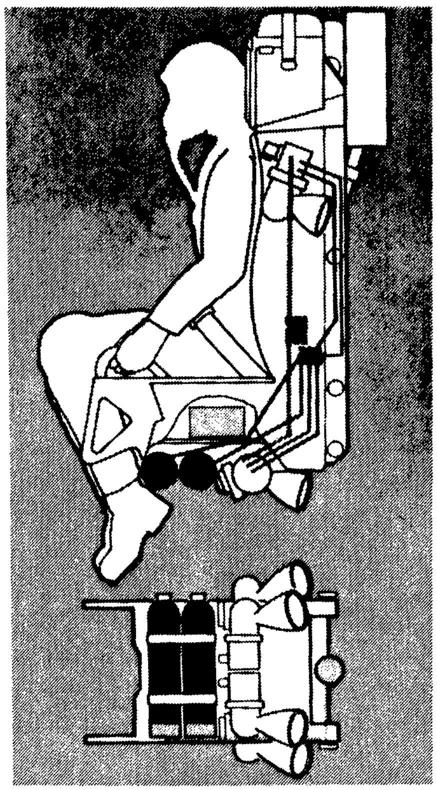
- Current ACS II ejection seats do not utilize three axis controllable thrust. The current seats are catapulted out of the aircraft, and a rocket motor ignites to provide upward motion. A small steerable thruster and gyro provide pitch stability. At low speed the seat tends to pitch forward and at high speed the seat pitches aft. The steerable motor corrects this tendency.

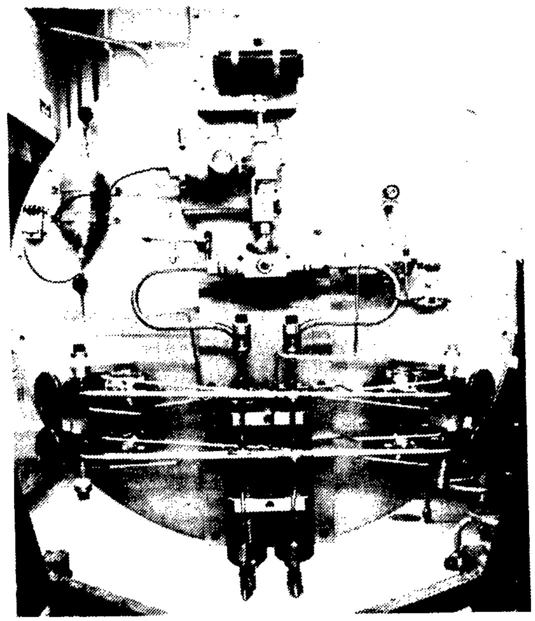
- The application of an advanced microprocessor with attitude gyros and throttable gel propellent fueled thrusters could provide increased capability for adverse ejection situations. At high speed the tremendous drag forces rapidly slow the seat down causing injuries. With controlled thrusters the seat can be slowed following a controlled profile. Studies show ejections at 800 kts and beyond could be within human tolerance levels. At low altitude the gyros sense position and provide controlled full power thrust to guide the seat into a horizontal position and fly it away from the ground. The microprocessor samples the gyros and commands the thrusters every 10 milliseconds.

- Tests were successfully completed on a brassboard ejection seat at TRW's Capistrano test site in April of 1989. Using scaled down 1500 lbf gel engines, full thrust was obtained in 8 ms of burn time. Pulse duty cycles were demonstrated at 2, 4, 6, 8, and 10 ms pulse durations. A total of 247 pulses were completed in about 1.5 seconds of test time. This test was the first complete system test for gel propellants.

- The tests were conducted by McDonald Douglas at TRW under Army Missile Command direction.

GEL TECHNOLOGY SPINOFFS— CONTROLLED EJECTION





BRASSBOARD

- POTENTIAL FOR SMART EJECTION SEATS WITH APPLICATION OF PROCESSORS, GYROS AND GEL PROPELLANTS
  - — HIGH SPEED EJECTION MORE SURVIVABLE DUE TO CONTROLLED SLOW-DOWN USING THROTTLEABLE THRUSTERS
  - — AVOIDS TUMBLING
  - — CAPABILITY FOR LOW ALTITUDE/ ADVERSE POSITION EJECTION WITH CONTROLLABLE THRUST LEVELS AND DIRECTION
- FIRST COMPLETE SYSTEM TEST OF GELS (APRIL 1989)
  - — 2 MILLISECOND VALVE RESPONSE TIME
  - — FULL THRUST ACHIEVED IN 8 MILLISECONDS
  - — 247 THROTTLE PULSES IN 1.5 SECONDS

90U 0097
16 Feb 90

BSTS GROUND DEMONSTRATION

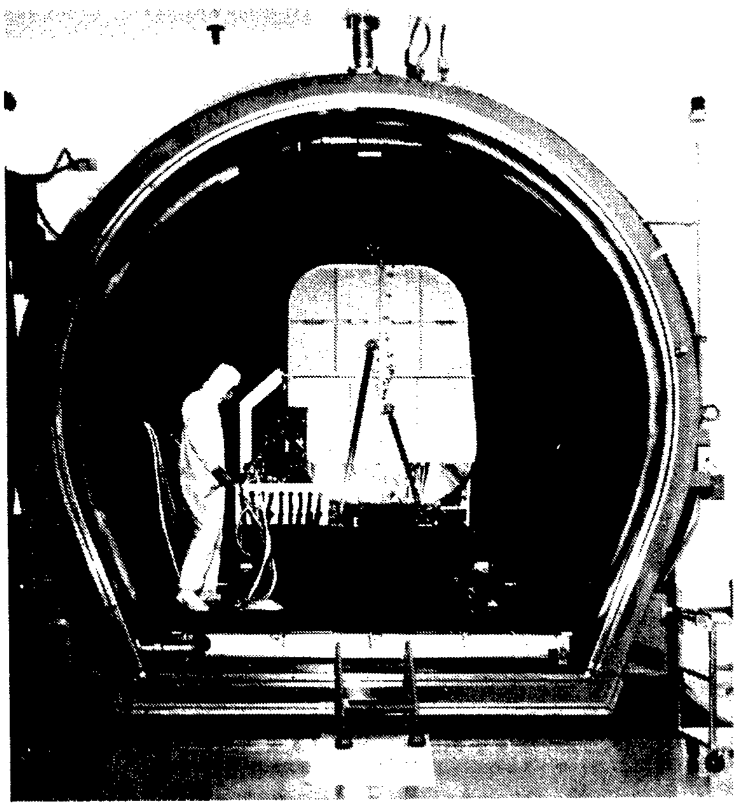
- The Boost Surveillance and Tracking System (BSTS) is an advanced space-based system capable of detecting and tracking ballistic missiles launched anywhere in the world. The BSTS will use infrared sensors to track the hot exhaust plumes of ballistic missiles. This system will replace the DSP system currently used for Tactical Warning/Attack Assessment (TW/AA). The BSTS will provide increased performance and capability meeting USSPACECOM requirements.

- There are two competing BSTS concepts undergoing extensive ground testing. The performance demonstrated has exceeded program goals. The infrared focal plane chips are shown. These new detectors have demonstrated increased sensitivity and uniformity. Manufacturing Technology programs have dramatically reduced the costs to produce these detectors.

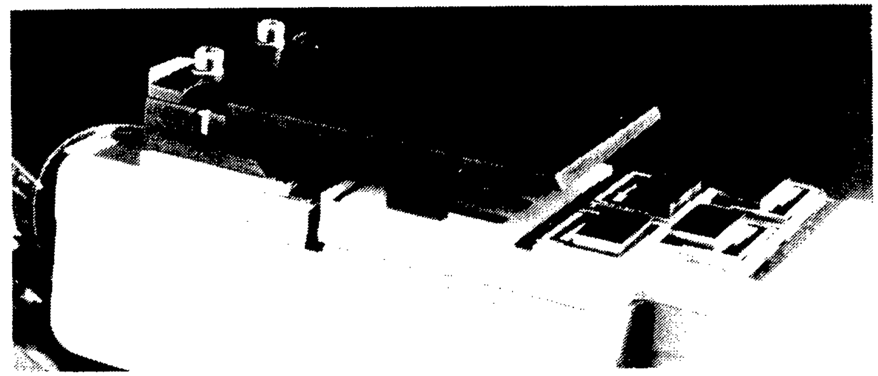
BSTS GROUND DEMONSTRATIONS

END-TO-END PERFORMANCE DEMONSTRATIONS OF THE BSTS PRIMARY SENSOR DESIGNS

GROUND TEST ARTICLE EVALUATED UNDER SIMULATED FLIGHT CONDITIONS (FOCAL PLANE, OPTICS, SIGNAL PROCESSING)

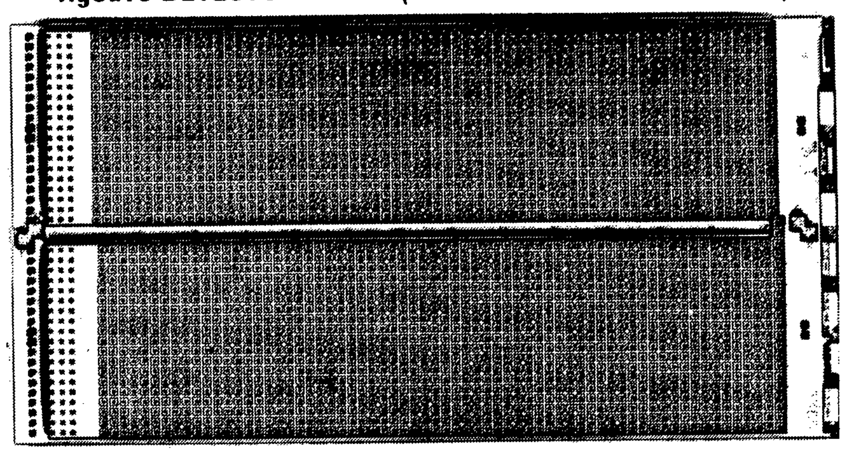


SINGLE FOCAL PLANE ASSEMBLY



- FLIGHT LEVEL PERFORMANCE AND PRODUCIBILITY DEMONSTRATED

HgCdTe DETECTOR ARRAY (EACH BLACK DOT IS A PIXEL)



90U-0251
26 Mar 90

CANDIDATE FOLLOW-ON ELEMENTS

- SDI is researching a number of technologies as candidate systems for follow-on Strategic Defense Systems. These advanced systems consist of a terminal phase interceptor called HEDI, both space-and ground-based lasers, neutral particle beam weapons and a terminal defense hypervelocity gun. The directed energy laser concepts could intercept attacking ballistic missiles and RV's at the speed-of-light. The neutral particle beam travels at near the speed of light. The terminal defense concepts of HEDI and HVG would intercept RV's in the final minutes of flight of the RV. The research into these advanced systems ensure the long-term effectiveness of a Strategic Defense System.

CANDIDATE FOLLOW-ON ELEMENTS

Element Name	Key Functions
HEDI - High Endoatmospheric Defense Interceptor	• Destruction Of RVs After Atmospheric Reentry
NPB - Neutral Particle Beam	• Destruction Of Boosters, PBVs, RVs And Defense Suppression Threats • Interactive Discrimination
SBL - Space-based Laser	• Destruction Of Boosters, PBVs And Defense Suppression Threats • Interactive Discrimination
GBL - Ground-based Laser	• Destruction Of Boosters, PBVs And Defense Suppression Threats • Interactive Discrimination
HVG - Hypervelocity Gun	• Destruction Of RVs In Terminal Phase

Technology Program Ensures Long-term SDS Effectiveness

jm-1319B / 032890

KITE-1 FLIGHT TEST

- Successfully completed 26 Jan 90, demonstrating:
  - Shroud operation and separation at high dynamic pressure (24,000 psf)
  - Warhead operation (used for flight termination)
  - Nosetip, forebody and window cooling

- <u>Summary of K-1</u>

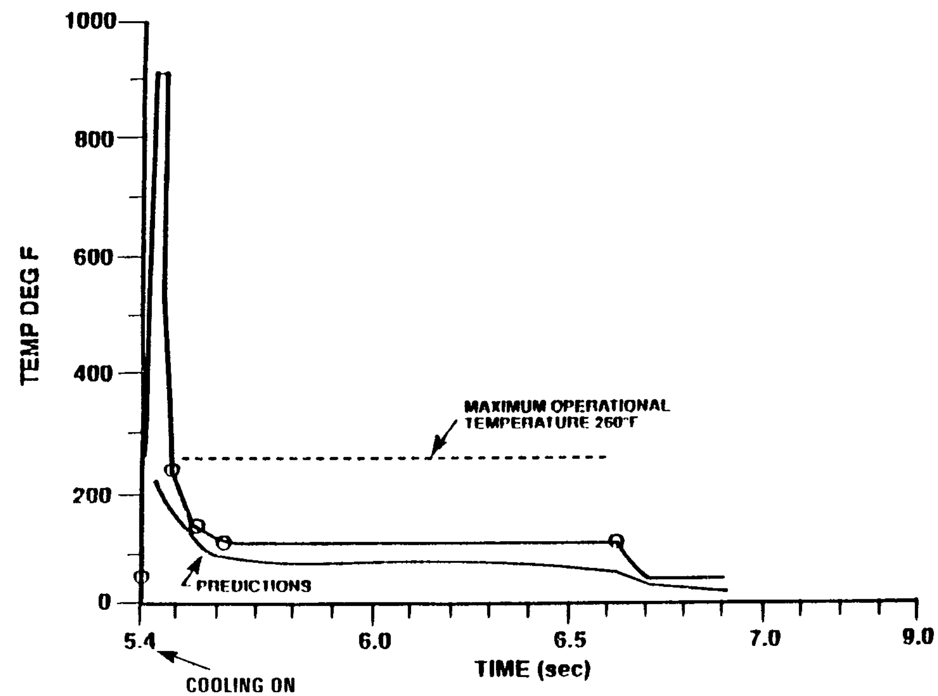
Time(s)	Event
0.00	Launch command, 1st stage motor ignition
1.60	1st stage burnout
1.65	1st stage separation
1.7	2nd stage ignition
3.9	2nd stage burnout (velocity 7800 fps (5318 mph))
5.3	Shroud separation command
5.4	Forebody & window cooling initiated
5.6	Window cooled from 900°F to 100°F
7.0	Flight terminated (warhead)

HEDI PROGRAM

1ST FLIGHT TEST 26 JAN 90

TECHNOLOGY ACHIEVEMENTS

- SHROUD REMOVAL AT HIGH DYNAMIC PRESSURE
- FOREBODY AND WINDOW COOLING
- WARHEAD DETONATION



90U 0081/1
23 Feb 90

NEUTRAL PARTICLE BEAM PROGRAM

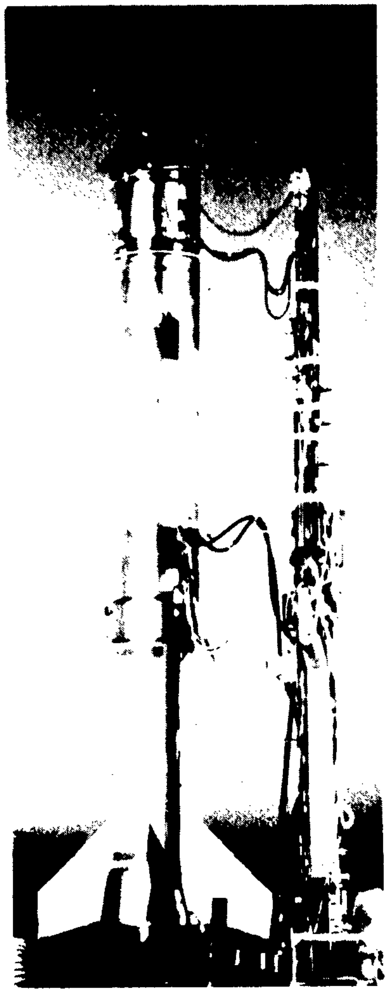
- The Strategic Defense Initiative Organization (SDIO) successfully conducted the first test in space of a Neutral Particle Beam (NPB) accelerator on July 13, 1989. Called BEAR, for Beam Experiment Aboard Rocket, the mission validated technology related to operating a NPB in the space environment and constituted a major milestone in the SDI effort. The NPB is a candidate technology for follow-on phases of a strategic defense system; the beam would be used to discriminate between attacking reentry vehicles and decoys and could also be used to kill missile boosters and warheads.

- Particle beam accelerators have been operated on the ground under controlled laboratory conditions for several decades. This experiment was important in demonstrating how the beam works in space without the hands-on control of the laboratory. Researchers had theorized how the beam would behave in space, but as is the case with any experiment, there were unknowns. The successful completion of this experiment permits researchers to focus and accelerate the NPB program.

- The BEAR Tests was launched from White Sands Missile Range, New Mexico, the sub-orbital flight test lasted just over nine minutes, with four minutes of actual NPB operation. Data collected will help researchers understand the operation of a particle beam in the vacuum of space, the effects of beam emission on the accelerator vehicle, the effects of the space environment on the beam, and the character of particle flux trapped in the geomagnetic field. The payload reached a maximum altitude of about 125 miles during the flight and was recovered about 50 miles downrange from the launch site.

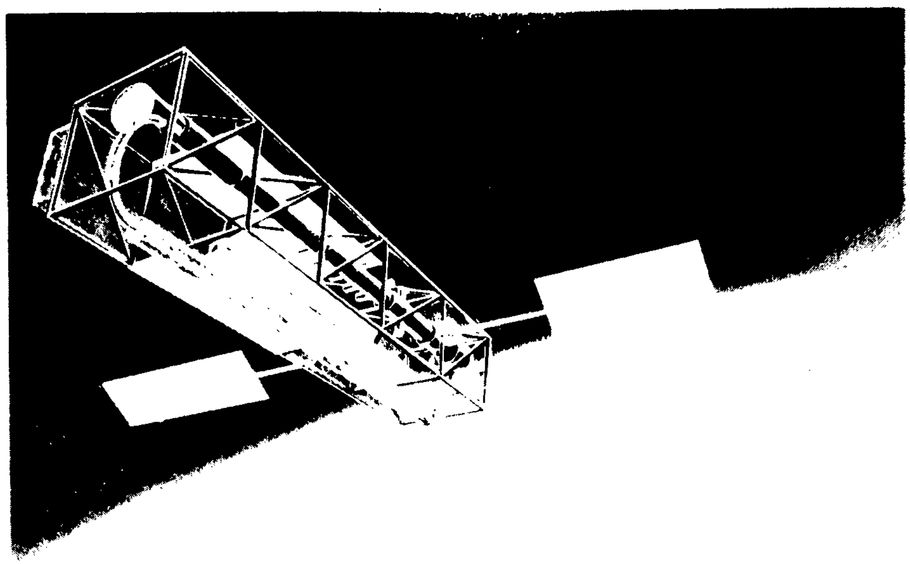
NEUTRAL PARTICLE BEAM PROGRAM

BEAR EXPERIMENT

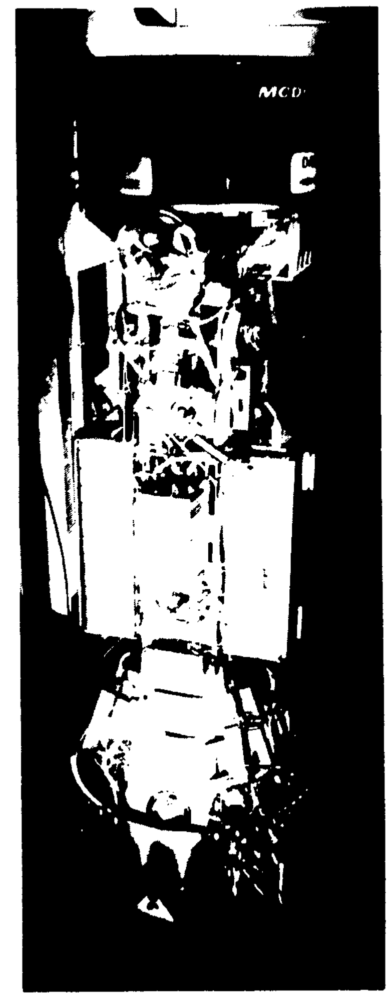


- SUCCESSFUL OPERATION OF PARTICLE ACCELERATOR (BEAR) 13 JUL 89 WAS FIRST OPERATION OF A DIRECTED ENERGY SYSTEM IN SPACE
- GROUND DEMONSTRATION OF PEGASUS FLIGHT HARDWARE 1992

CONCEPT



BEAR PAYLOAD



890 1007
23 Feb 90

SPACE-BASED CHEMICAL LASER PROGRAM

- Space-Based Chemical Laser (SBCL) battle platforms are being developed to complement the initial Phase I deployment. A constellation of several tens of such platforms provides an additional layer of defense with unique speed-of-light capabilities. The powerful beam arrives at the target nearly instantaneously, burning through and destroying booster rockets and post-boost vehicles in fractions of a second. The platform is able to distinguish warheads from decoys by their response to the high-power beam. Lethal beams can be projected to the cloudtops, so boosters can be engaged at the earliest possible time.

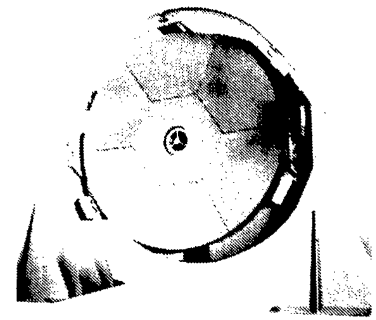
- The Alpha laser has been developed to generate such powerful beams with space hardware. Alpha became operational in April, 1989.

- Technology for fabricating the large pointing mirror has been validated with LAMP, a subscale demonstrator. LAMP is several times larger than the Hubble Space Telescope.

- The next research step for the SBCL is integrated testing. The Alpha-LAMP ground test will project a stable, well-focused high-power beam from a large telescope. The Complementary Space Experiment (CSE) in 1993 integrates a smaller laser and mirror system for a series of experiments which answer fundamental questions about the operability of this platform. These experiments will conclusively resolve the basic engineering issues for these remarkable defensive weapons.

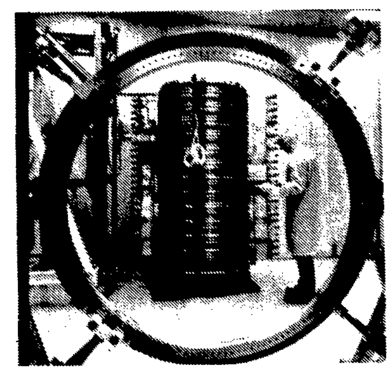
SPACE BASED CHEMICAL LASER PROGRAM

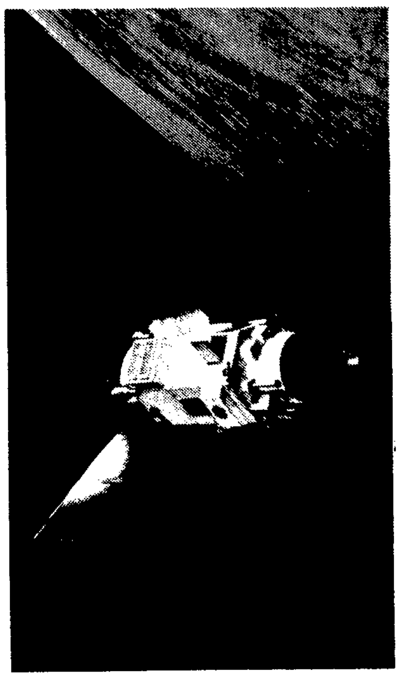
LAMP MIRROR DELIVERED



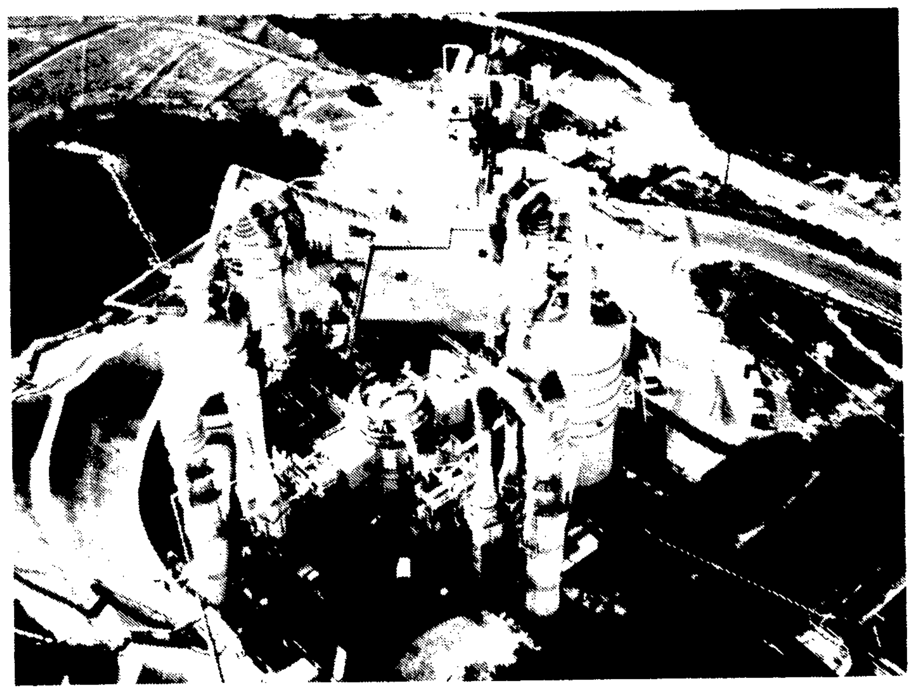
- FIRST GROUND TEST OF ALPHA LASER DEVICE—APRIL 1989
- ALPHA-LAMP INTEGRATED GROUND TEST—1992
- LOW POWER COMPLEMENTARY SPACE EXPERIMENT (CSE)—1993

ALPHA LASER ELEMENT





CSE VEHICLE



GROUND TEST FACILITY
ALPHA TEST SITE

90U 0144
23 Feb 90

FREE ELECTRON LASER PROGRAM

- The Free Electron Laser (FEL) works on the principle of transfer of energy from a relativistic electron beam to an accompanying beam of light. This transfer is caused by a series of transverse magnetic fields that from a structure called a wiggler. The wavelength of the light that a FEL produces can be varied by changing the parameters of the electron beam or those of the wiggler. Because the FEL is on the ground, it has virtually unlimited run time giving it a flexibility denied other weapon systems.

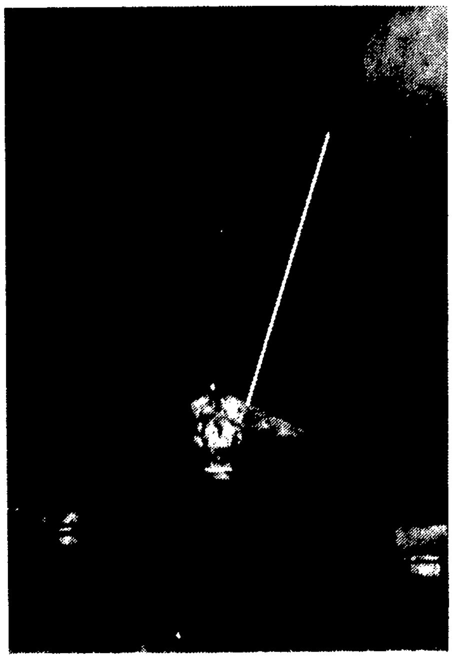
- In the case of the ground-based FEL, the laser must be transmitted through the atmosphere to space and then reflected by an orbiting mirror that would precisely point the beam at the target. The Low-Power Atmospheric Compensation Experiment (LACE) and the Relay Mirror Experiment (RME) satellites launched in Feb 1990 are key experiments for the ground-based FEL concept. The LACE satellite will measure the quality of a laser beam transmitted to space. The RME satellite will demonstrate how a laser beam can be reflected from a space mirror and pointed at a target board.

- SDI has demonstrated wavelength scaling to 0.5 microns which is twice as difficult as the 1.0 micron wavelength to be used on the laser weapon. The Boeing FEL facility is undergoing a series of upgrades that will demonstrate lasing in the configuration to be used in the eventual weapon.

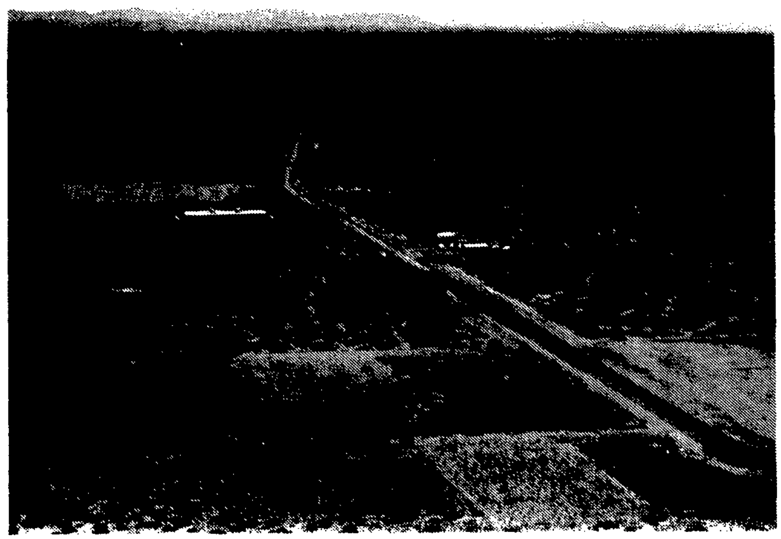
- All support facilities will be completed at the White Sands FEL test range by the end of FY90. this will allow the start of the technical facilities in FY91.

FREE ELECTRON LASER PROGRAM

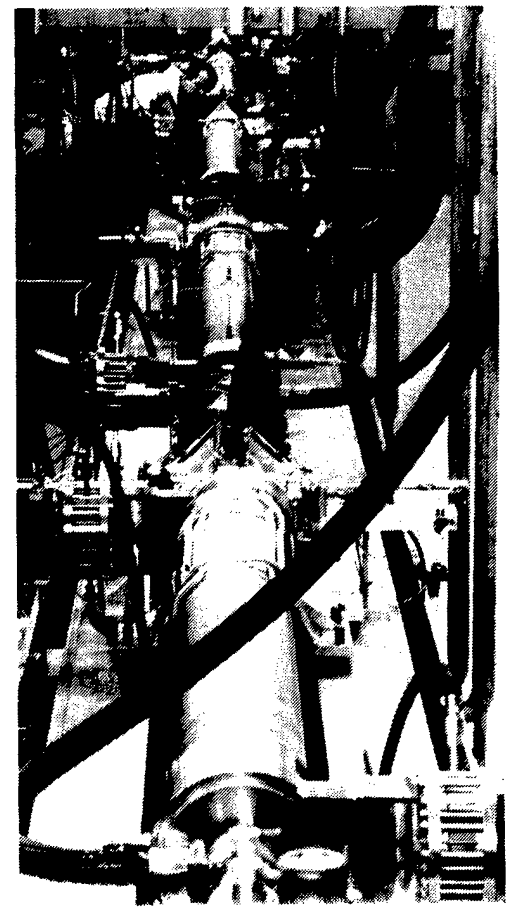
- SCALING TO VISIBLE WAVELENGTHS DEMONSTRATED 1989
- RELAY MIRROR AND LOW-POWER ATMOSPHERE COMPENSATION EXPERIMENTS LAUNCHED 14 FEB 1990
- LASER SCALABILITY DEMONSTRATION—1991



RME SCORING AND CONTROL CENTER
KEHEI, HI



FEL TECHNOLOGY INTEGRATION SITE
WHITE SANDS, NM



VISIBLE WAVELENGTH
FEL LABORATORY

90U-0143/1
4 Apr 90

SUMMARY

- I believe that the most significant evidence of progress during the six year history of the SDI program is that we now have:

  - A Phase I architecture that will meet the requirements for strategic defense, based on technically achievable sensors, command and control capability, and interceptors:

  - Reasonable cost projections for such a system;

  - A set of technology development projects that support Phase I as well as follow-on systems that could employ advanced concepts such as lasers and neutral particle beams; and

  - A national strategic defense research and development infrastructure, staffed with extremely talented and dedicated professionals, that stands ready to resolve the remaining technical and engineering issues of strategic defenses.

- SDI research is an excellent investment. That is why, in an era of scarce defense resources, the President is so supportive of the program. We continue to show impressive results. You can be assured that significant technological advances which occur in the future will be exploited to further reduce the cost and improve the performance of a prospective strategic defense system. Our past record amply supports this commitment.

SUMMARY

- Technology At Hand To Develop And Deploy Strategic Defenses
  - Supported By Many Independent Evaluations By The Scientific Community
  - Engineering Task Is Challenging - Team In Place
- Planned Phase I Architecture Defined
  - Meets JCS Requirements
  - Cost Reduced From $69B To $55B (FY 88 $)
- Research On Interceptors, Lasers And Particle Beams Provides Viable Future Options For Requirements And Architectures Beyond Phase I

FOLLOW-ON BRIEFINGS

Briefings

- Brilliant Pebbles
- Cost Reduction Efforts
- Directed Energy Programs
- Sensor Programs
- Kinetic Energy Programs
- Mission Performance / JCS Requirements
- NTB & System Simulation
- Technology Applications
- Countermeasures Research
- Survivability / Lethality Program

FOLLOW-ON VISITS

Visits

Emphasis	Locations	Duration
Brilliant Pebbles	California / Colorado	2 1/2 Days
KEW / Sensors	California	3 1/2 Days
DEW	California / New Mexico	2 1/2 Days
LPS	California	2 1/2 Days
Theater Defense	Alabama / Texas	2 1/2 Days
BSTS	New York	1 Day
Medical FELaser	Massachusetts	1 Day
DEW / Discrimination	Massachusetts	1 Day
DEW	New Mexico	2 1/2 Days

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